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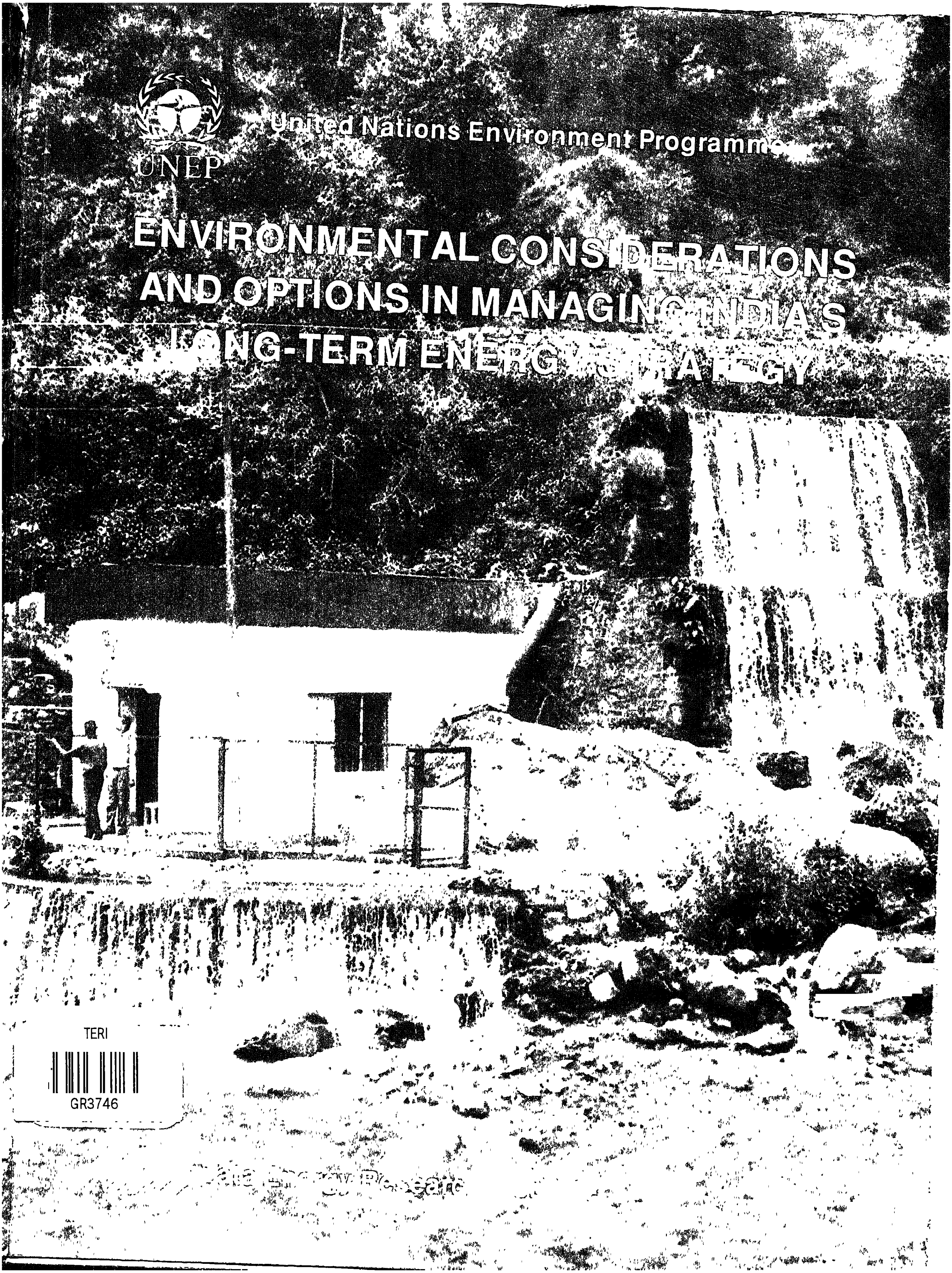
ENVIRONMENTAL CONSIDERATIONS AND OPTIONS IN MANAGING INDIA'S LONG-TERM ENERGY STRATEGY



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Tata Energy Research

ENVIRONMENTAL CONSIDERATIONS AND OPTIONS IN MANAGING INDIA'S LONG-TERM ENERGY STRATEGY (ECO MILES)

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List of abbreviations

ATF : Aviation and turbine fuel
BHH : Bayer Hall Heroult
BkWh : Billion kilowatt hours
CEA : Central Electricity Authority
CIF : Cost including insurance and freight
CMIE : Centre for Monitoring Indian Economy Private Limited
CNG : Compressed natural gas
COG : Coke oven gas
CPC : Calcined petroleum coke
CRRI : Central Road Research Institute
CSE : Centre for Science and Environment
DSIR : Department of scientific and industrial research
DSP : Durgapur Steel Plant Limited
EDSG : Energy demand steering group
ESI : Energy survey of India
ESP : Electrostatic precipitators
ETPs : Effluent treatment plants
FAI : Fertilizer association of India
FCC : Fluidized catalytic convertor
FGD : Flue gas desulphurisation
FO : Fuel oil
Gcal : Gigacalories
GCV : Gross calorific value
GDP : Gross domestic product
GWh : Gigawatt hours
HEMM : Heavy earth moving machinery
HHS : Hot heavy stock
HSD : High speed diesel
HYV : High yield variety
IGCC : Integrated gasifier combined cycle
IISCO : Indian Iron and Steel Company Limited
INIOH : Indian National Institute of Occupational Health
IREP : Integrated rural energy planning
IWT : Inland and water transport

kcal : Kilocalories
kgoe : Kilograms oil equivalent
kgs/ha : Kilograms per hectare
kWh/y : Kilo watt hours per year
LPG : Liquefied petroleum gas
LSHS : Low sulphur heavy stock
MCFC : Molten carbon fuel cell
MEROX : MERcaptan oxidation
MW : Megawatts
MGR : Merry-go-round
MINAS : Minimal National Standards
MJ : Million joules
MNES : Ministry of Non-conventional Energy Sources
MPs : Mechanical precipitators
Mtoe : Million tonnes oil equivalent
NCAER : National Council of Applied Economic Research
NSSO : National Sample Survey Organization
NTPC : National Thermal Power Corporation
PFBC : Pressurised fluidised bed combustion
PHHs : Polynuclear aromatic hydrocarbons
PLF : Plant load factor
PSE : Public sector enterprises
REDB : Rural energy database
RETs : Renewable energy technologies
RSP : Rourkela Steel Plant Limited
SAIL : Steel Authority of India Limited
SCRs : Selective catalytic reducers
SEBs : State Electricity Boards
SKO : Superior kerosene oil
SPM : Suspended particulate matter
T and D : Transmission and Distribution
TEL : Tetraethyl lead
TISCO : Tata Iron & Steel Company Limited
toe : Tonnes of oil equivalent
TPS : Thermal power stations
WGEP : Working group on energy policy

सत्यमेव जयते
मंत्री
पर्यावरण एवं वन
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FOREWORD

Economic development in India has, historically, been based on a great concern for nature. This reality was very evident right uptil the early 1800s. During the colonial period, India witnessed a rapid exploitation and degradation of its natural resource base, which resulted from a disempowerment of age-old local institutions and large scale, low price export of timber from India to Britain.

Mahatma Gandhi, the leader of India's freedom struggle, when asked if he would like to have the same standard of living for India's teeming millions as was then prevalent in England said, "It took Britain half the resources of the planet to achieve this prosperity. How many planets will a country like India require!" Mahatma Gandhi also had the foresight to say: "Europeans will have to remodel their outlook, if they are not to perish under the weight of the comforts to which they are becoming slaves..... A time is coming when those who are in a mad rush today of multiplying their wants, will retrace their steps and say: what have we done?". His words seem to have proved truely prophetic.

In recent years, environmental policies and legislation have evolved in India, providing a comprehensive framework to guide economic development along an environmentally friendly path. The last few years have also witnessed major economic reforms resulting in rapid development of all sectors of the economy - agriculture, industry, transport and infrastructural projects. Correspondingly, this period has also seen a mushrooming of environmental NGOs in the country reflecting concerns, at the grassroots level, for the adverse environmental consequences of this pace and structure of development.

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The energy sector in India, as in most other countries, can and does contribute significantly to adverse impacts on the environment - be it the combustion of the more modern energy forms such as, coal, oil and gas or the use of biomass energy forms resulting in forest and soil degradation and associated impacts. The study undertaken by the Tata Energy Research Institute (TERI) on "Environmental Considerations and Options in Managing India's Long Term Energy Strategy (ECOMILES)", which is a part of UNEP's series of projects entitled, "Environmentally Sound Energy Development" provides some very useful directions for the growth of the energy sector incorporating environmental considerations. The study clearly brings into focus the energy requirements of proposed economic growth paths, and their sustainability from both the energy and environmental perspectives. Alternative energy supply and use paths have been defined, evaluating these in terms of environmental benefits, import-export implications, and investment and technological requirements. The study also points towards those areas where policies and institutional structures need to be strengthened to take care of the energy demands and the environmental effects of the new economic scenario in the country.

The process of economic reforms in the country is irreversible and the need for accelerated growth indisputable. The issue really is one of how this can be achieved with the maximum resource use efficiency. This study, based on three years of desk and field research by TERI, provides a comprehensive understanding of the environmental impacts of energy development and the trade-offs involved in pursuing alternative paths.

(KAMAL NATH)

NEW DELHI

JULY 31 1995

Foreword

Environmentally Sound Energy Development in India

by

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Executive Director, UNEP

A great many of the environmental problems confronting mankind at the present time are connected, one way or another, to the extraction, conversion, transformation or use of energy. This is the principal reason why a thorough understanding of energy and environment interactions is a prerequisite for planning and implementing sustainable development. The role of energy in sustainable development has been acknowledged by various stakeholders as one which should be understood from both economic and environmental perspectives. In awareness of this, the United National Environment Programme (UNEP) has embarked on country-specific projects which would enable us to assist member countries to investigate and discuss in detail the issues which are connected to energy, environment and development. Two case studies have been initiated in India and in The People's Republic of China (PRC).

The objective of the Indian study was not limited to the need for understanding how to factor environmental criteria into energy policy and planning. It was also aimed at promoting environmentally benign energy production and use. The chance of success in achieving the long-term goals of the studies was enhanced by setting realistic short-term objectives. These include building on existing planning models, methods and databases, sensitization of energy planners through national workshops, and sharing of the Indian experience with experts from countries in the region. Via the guidance of international and national steering committees, and the technical support of the UNEP Collaborating Centre on Energy and Environment (UCCEE) Riso, Denmark, the Tata Energy Research Institute (TERI) arduously implemented the project in collaboration with the Ministry of Environment, Government of India between 1992 and 1995. In the course of this exercise, the knowledge of a number of Indian experts has been enhanced in the field of energy and environment, issues that would be of essential use to Indian energy planning and development have been unravelled and a comprehensive energy-related database has been constructed. In addition, a general strategy for carrying out this type of study has emerged.

After the conclusion of the study, the outcome of the exercise was shared with countries in the region in order to obtain their suggestions as well. This was done in February 1995 with experts from China, Sri Lanka and Thailand in attendance. This publication contains a synthesized output of the study which has been enriched with the comments from experts from the region. Beyond the actual and potential benefits to the Indian experts and policy makers directly involved in the exercise, I believe that this publication can have wider positive effects. It will be of use to researchers, policy makers, energy engineers and economists worldwide. It contains a description of extensive experience on how to approach energy-environment issues, with lucid and doable recommendations, both for specialists and non-specialists in the energy field. I am sure that this publication will also serve as relevant input to global activities in the field of sustainable energy planning, not least because it deals with a highly populated country in an economically dynamic region of the modern world.

A few central energy-environment issues have emerged from this report. First, it is obvious that the demand for energy is increasing, but that the supply is limited. This pressure in fulfilling demand threatens economic growth and tends also to encourage the use of environmentally damaging forms of energy. This is especially true at the household level and in the industrial sector. Second, constraints in the development and expansion of the energy sector, along with inadequate maintenance and upkeep of energy equipment, leads to inefficiency in energy utilization and an increase in pollution. Third, the rural areas have their unique problems, especially because they depend heavily on biomass energy resources which are often utilized rather inefficiently. These and other related issues are analyzed and discussed in detail in this publication.

Finally, I wish to thank those who have been involved in the various stages of research and advisory activities and in the workshops that have led to this publication. Especially, I sincerely acknowledge the cooperation of the various arms of the Government of India with the project implementors - the Tata Energy Research Institute. The technical support given by the UNEP Collaborating Centre on Energy and Environment is also appreciated. I commend the role of the National and International Steering Committees whose guidance must certainly have boosted the assiduous efforts of TERI. I am confident that policy makers, researchers, and other users of this report will find a great deal of useful material for their potential activities in the area of energy, environment and sustainable development.

Preface

This report deals with a set of issues that would be of increasing importance in India's future development strategy. It is always difficult to incorporate the diverse concerns and considerations that guide the complex set of policies inherent in energy decision making in any society, but in the case of India, the task is particularly difficult. Firstly, there are economic compulsions that require rapid growth of energy supply and consumption to fuel the developmental activities necessary for alleviating poverty in the country. Secondly, there are marked differences in patterns and levels of consumption of energy across different sections of Indian society, such as excessive reliance on biomass energy forms in rural areas and rapid growth in the consumption of conventional forms such as petroleum products and electricity in the transport and industrial sectors. These two sets of supply and consumption patterns also imply very different sets of environmental problems. For instance, in rural areas, burning of very low calorific value fuels in homes, generally without proper ventilation, leads to high levels of indoor pollution. In the case of the industrial sector, energy use leads to environmental impacts along an extensive cycle which often starts with coal mining, and includes coal transportation, power generation and disposal of fly ash, all of which have adverse impacts on the environment in different stages and at different levels.

This study, therefore, covers the linkage of energy activities with macroeconomic variables to start with and then deals with issues related to energy reserves and production, and trends in energy consumption in various sectoral components including major industry groups, the transport sector, households and agriculture. It then deals with a detailed analysis of the environmental impacts of energy production and use, ranging from land degradation to the environmental effects of nuclear power plants and the effects of energy use on the environment in a number of industrial activities. Since the purpose of the study is to help in tackling a set of energy policies in consonance with environmental goals, it, therefore, covers future prospects of energy consumption and supply and a discussion and evaluation of an optimal energy path, both on a business as usual basis as well as for scenarios developed by incorporating environmental considerations through a set of policies and strategies that are discussed in extensive detail.

In a country as large and diverse as India, aggregate analysis often fails to convey the reality at the ground level. Hence, the study has focused on specific case studies at the micro level which help to concentrate on the issues that are the building blocks and, hence an important part, of macroeconomic considerations, but these may not be revealed if only aggregate analysis was to be provided to draw important conclusions.

The case studies, therefore, support policy considerations that are analysed and discussed in the report, and a careful blending of the conclusions from the macro analysis and the case studies has been attempted in defining the strategies developed in the project.

The report, in essence, presents a set of policy measures and action plans that would underlie an energy development path for the future that is supportive of the objectives of growth, so vital for the alleviation of poverty in India, but also provide environmentally sustainable solutions that would in turn support the welfare of Indian society. Lastly, it needs to be emphasised that this report is merely in the nature of the beginning of a dialogue that perhaps needs to be carried through much further before policies and action plans can be enshrined within the decision making structures and processes of economic development in India. It would be essential to nurture and sustain this dialogue in the months and years ahead.

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- South India Textile Research Association
- Ahmedabad Textile Research Association
- Chemical Manufacturers Association
- Chlor Alkali Manufacturers Association
- Ministry of Industry
- Ministry of Environment & Forests
- Fertilizer Association of India
- Indian Sugar Mills Association
- National Federation of Sugar Cooperatives
- Cement Manufacturers Association
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- Karnataka Forest Department

- Centre for Ecological Sciences, Indian Institute of Science, Bangalore
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- Central Institute of Agricultural Engineering, Bhopal
- Voluntary Health Association of India
- M/s Swaminathan Research Foundation, Madras
- Commonwealth Institute of Biological Control, Bangalore

Any errors or omissions in this report, however, are the responsibility of the project team and the coordinators.

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Genesis and scope of the study

Energy policy-makers are beginning to invest increased attention on the degradation of the environment at the local, regional and global levels, caused by current patterns of energy production and use.

At the national and local levels, the concern is focused on such issues as emissions from the combustion of fossil fuels in power stations, from motor vehicles, or from industrial use. On the global level, the major concern is the build-up of greenhouse gases in the atmosphere, which is expected to cause significant climatic changes if emissions continue at the present rate of growth. Emissions of carbon dioxide—mainly from the combustion of fossil fuels—is recognized as the main contributor to this greenhouse effect. In addition, when other important sources of greenhouse gases such as agricultural practices and deforestation are considered, it becomes evident that the short term possibilities to reduce emissions lie within the energy sector.

In view of the growing concern regarding environmental problems at the regional and global level, in its 15th session in May 1989, the Governing Council of UNEP emphasized the promotion of strategies for action in developing countries. It was stressed that these strategies should aim at making the optimum use of energy production and consumption systems which are safe, affordable and efficient while simultaneously minimizing the negative impacts on the environment. These objectives should be met without impeding the impetus of the development process in these countries. Hence, such a line of action would necessitate increased energy efficiency, transfer of efficient technologies to developing countries, and the development of endogenous capacity and use of renewable energy resources.

It is generally recognized that the existing level of greenhouse gases is largely a result of activities of the developed world. Nevertheless, developing countries are equally subject to environmental impacts associated with these activities. UNEP, therefore, considers the participation of developing countries in current international negotiations in order to reach agreements that address environmental problems without constraining the economic development of the developing world, while at the same time, identifying ways and means of securing the funding and transfer of technology.

UNEP plays a catalytic role in initiating and supporting the formulation of national energy policies, with special emphasis on environmental issues, a line strongly supported at the 16th Governing Council Meeting in May 1991.

It is in accordance with this line of action that UNEP developed the proposal for the study on *Environmentally Sound Energy Development*, conducted jointly with the Government of India.

The primary long-term objective of the study is to contribute towards the integration of environmental criteria in energy policy and planning, especially in developing countries, and to promote more environmentally benign energy production and use in order to achieve environmentally sound energy development. Short-term objectives of the study include:

- enhancement of technical and political awareness in India regarding environmental impacts of energy production and use, in general, and in the field of atmospheric pollution, in particular,
- strengthening existing institutional capacity and the base of scientific and technical data for the development and implementation of environmentally sound and cost effective energy policies and technologies in India, and
- identifying economic, institutional and technological factors that constrain the implementation of more environmentally benign energy systems.

Measures towards the successful accomplishment of the short-term objectives would include:

- active participation in the preparation, and later, adoption of specific time-bound energy policy measures, both as a part of an international climate convention, and as an integrated part of national energy policy, which *inter alia* would result in the reduction of atmospheric pollution and other negative environmental impacts,
- active participation of a number of institutions and energy professionals in the project and continued implementation of the plan of action, and
- ensuring that the quality of established information and databases on energy related environmental impacts is maintained.

In the long run, the success of the project would be indicated by the adoption of more environmentally sound energy policies in India and, at a later stage, in other countries in the region.

The project was expected to generate the following outputs:

- setting up a plan of action for implementation in India on energy requirements needed to secure national development aims with minimal negative impacts. This plan was expected to have specific-time bound national implementation programmes, funding and technology requirements for energy efficiency, renewable energy and development of endogenous capacity,

- modification and enhancement of traditional planning models and methods, by building on existing Indian energy planning experiences in order to incorporate environmental considerations,
- quantification of major environmental impacts of energy production and development of a database to use these in the planning process. The existing UNEP/SEI database will be utilized appropriately, and
- contributing towards the sensitization of the energy planners in the Ministry of Energy, the National Planning Commission and research institutions to the environmental aspects of energy development through small workshops and informal training.

In the final analysis, the project is expected to facilitate the implementation of more environmentally sound and cost-effective energy policies and technologies in India. In addition, the outputs from the project would provide UNEP and other international organizations with a firmer base for the orientation of their energy-environment activities.

Executive Summary

India is a populous country accounting for nearly a fifth of the world's population. While it is rich in natural resource wealth, inadequate availability of capital and technological resources has resulted in a resource-inefficient development path.

Energy resources are a basic building block of any economy. India is abundantly endowed with coal and renewable energy in the form of solar, wind and hydel energy and has significant hydrocarbon resources as well.

Proven energy resources

	Unit	*India*	*World*	*India as a % of the world*
Coal	Bt	59.0	1078.1	5 47%
Oil	Bbbl	5.91	1009.2	0.59%
Natural gas	Tcm	0.730	119.2	0.61%
Hydropower	MW	94 000	n a.	

Sources
1/ World Energy Council (WEC), 1992
2/ British Petroleum (BP), 1991

However, economic growth has been plagued by deficient energy supply—both in terms of quality and quantity. The perpetual race to narrow the demand-supply gap in energy, resulted in suboptimal decision making in almost all the energy sectors: hydro power development lost to the shorter gestation thermal power plants; generation capacity expansion took precedence over proper maintenance and reduction of losses in the transmission and distribution network; the focus of energy planning was on supply enhancement with little or no attention being given to demand management; opencast coal mining methods were preferred over underground mining; and highly inadequate resources were put aside for research and development work.

Thus, while coal production grew at an average annual rate of over 5.5%, the ash content of coal simultaneously increased from about 30% in early 1970s to 40–45% in the early 1990s, leading to increased transportation costs as well as inefficiencies in operation of coal-based activities. The share of hydro power capacity declined from 45% in the early sixties to about 28% in 1993 creating load scheduling, and exacerbating management problems. Despite a growth of 10% per annum in electricity generation over the period 1950–1991, electricity and peak energy supply fell short of demand to the tune of 8.5% and 17.3% respectively in 1991/92. The T & D losses increased from 14.6% to 22.8% in this period. Unreliable and poor quality supply of the above energy forms led to an increased dependence on hydrocarbons, oil products, in particular. As such, oil consumption averaged a growth of 5.4% per annum over the period 1971–1994, despite the two oil price shocks.

The pressure of fuelling economic growth also resulted in scant regard being paid to the pattern and pace of resource depletion as well as the pollution caused by the energy cycles.

- Analysis of satellite imagery forest cover data shows that from 1972–75 to 1980–82, the area of closed and open forest cover declined from 55.52–46.35 million hectares (or 16.9–14.1% of the total land area), a loss of about 1.2 million hectares per year. While the assumption on the correlation between fuel use and deforestation has weakened over time, where forest depletion has already taken place, fuelwood demand may also be contributing to further degradation.
- Biofuel smoke has been established as a risk factor causing acute respiratory infections (ARI), the chief cause of infant mortality in the Third World, accounting for nearly 650 000 deaths in India annually (Smith 1993). The incidence of *cor pulmonale*, a heart disease, is found to be high among North Indian women. Biomass pollution has also been linked to pregnancy-related problems among women.
- While industry is recognized as a major polluter, little authentic data is available to present actual levels of pollutant emissions and consequent impacts. However the report presents in detail the emission standards and the status of adherence to them by various groups of industries.
- Thermal power plants in the country consumed over 162 Mt of coal in 1993/94, generating over 62 Mt of fly ash and bottom ash to be disposed off.
- An estimation of carbon dioxide emitted by the road transportation sector in the metropolitan cities in 1990 shows that Delhi has contributed over 700 000 tonnes while approximately 500 000 tonnes have been contributed by Bombay. Motor vehicles in India contribute to about 0.52% of the total CO_2 emissions from road transport all over the world.
- A study by CPCB on the ambient noise levels in some metropolitan cities shows that the noise levels in most of the cities exceeds the prescribed standards and that vehicles are the major source of noise.

The present position in the country *vis-a-vis* reserves of hydrocarbons, forest cover, urban environment, water quality and environmental health problems necessitates a long-term evaluation of following present development paths against the cost of alternative, environmental and resource-efficient development paths.

The TERI Energy Economy Simulation and Evaluation (TEESE) model is a demand-driven linear programming model minimizing energy system costs. It is built around the Reference Energy System (RES) which maps primary energy sources to secondary sources and ultimately to the end uses. The TEESE model, with appropriate environmental constraints built in, is used here to project energy and environment implications of the defined economic growth paths for the terminal years of the 8th, 9th, 10th and 11th Five Year Plans.

The outputs that the model provides are in terms of the:

- optimal primary energy supply mix,
- optimal level of import and export of various fuels,
- optimal fuel mix use pattern in various sectors,
- optimal modal mix in the transport sector,
- technology-wise optimal generation and capacity mix,
- optimal energy system cost,
- resource requirement, and
- emission levels of different pollutants.

Scenarios

The various scenarios that have been developed are as follows:

Business-as-usual scenario

It is assumed that the present energy supply and use pattern will persist with some marginal changes within the time frame of the study. In the transport sector, the model assumes that the trend of rapid shift to private modes of transport from the public mode will continue as exhibited in the past. Similarly, in the agricultural sector, the existing diesel pumpsets will be completely replaced by electric pumpsets. In industry, marginal improvements in energy efficiency are considered.

On the supply side, it is assumed that crude oil and natural gas production would be at the levels of 47 Mt and 36 Bcu.m respectively in 2001. However, this production level has been frozen beyond 2001. Domestic non-coking coal production is assumed to grow at a rate of 6% per annum, whereas coking coal supply has been kept at 50 Mt and 60 Mt respectively in 1996 and 2001. Beyond that, the annual production will remain constant at 70 Mt. For the power sector, marginal improvement in plant load factor, auxiliary consumption and conversion efficiency for thermal power plants a reduction in T & D losses and improvement of the system load factor of the utility system is taken into account. Further, import of natural gas at a price of US $2.5 (c.i.f.) per 1000 cubic metres (Nm^3) has been allowed from 2006.

Scenario I. This scenario considers energy conservation measures such as improvement in coke rate, reduction in industrial process heating energy and electricity requirement, improvement in agricultural pumpsets, reduction in T & D losses over the BAU etc. Since conservation measures generally take time to be implemented and since 1996 is only two years ahead, these options have been considered from the Ninth Plan.

Scenario II In this scenario, higher capacity additions in Renewable Energy Technologies (RETs) like wind and small hydel are considered. Also, biogas availability is higher than the BAU scenario The addition of nuclear capacity is not contingent on its cost features but is fixed at 10 000 MW by 2011.

Scenario III The two technologies considered here are the Integrated Gasifier Combined Cycle (IGCC) and the Molten Carbonate Fuel Cell (MCFC) technology. It is assumed that these two technologies will be commercially available in India in 2006 and afterwards.

Scenario IV. This scenario considers the development of a higher hydro potential to the tune of 10 000 MW.

Scenario V. In this scenario, firewood supply has been frozen at 200 Mt from 2001 and onwards.

Scenario VI In this scenario, all the measures undertaken in Scenarios I–V are considered simultaneously.

Low population scenario

In the BAU scenario, population growth rate has been taken as 2.01% during the period 1991–96 and 2 per cent beyond that. In this scenario, the population growth rate has been taken as 1.77%, 1.69%, 1.54% and 1.40% respectively during the periods 1991–96, 1997–2002, 2002–2007 and 2012.

Summary and conclusions

The tables below give a comparison of the results of the various scenarios in terms of energy system costs and pollutant emissions.

(Unit: Rs Billion)

	1996/97	*2001/02*	*2006/07*	*2011/12*
BAU	1671	2277	3085	4112
Scenario I	—	2167	2945	3938
Scenario II	—	2299	3122	4160
Scenario III	—	—	3117	4158
Scenario IV	—	—	—	4111
Scenario V	—	—	—	4202
Scenario VI	—	—	—	4119
Low population scenario	—	—	—	3600

Pollutant	*2011/12*								
	Units	*BAU*	*Sc I*	*Sc II*	*Sc III*	*Sc IV*	*Sc V*	*Sc VI*	*Low population scenario*
SPM	Mt	434.00	408.00	503.00	431.00	433.00	434.00	330.00	430.00
SO_x	Mt	0.16	0.09	0.16	0.13	0.16	0.16	0.15	0.16
NO_x	Mt	2.82	2.40	2.70	2.77	2.83	2.89	2.04	2.80
CO	Mt	22.00	21.70	19.30	21.90	21.40	18.20	18.80	19.80
HC	Mt	0.59	0.51	0.52	0.56	0.60	0.60	0.40	0.57
CO_2	MtC	736.00	684.00	727.00	725.00	727.00	687.00	591.00	700.00

Clearly, there are economic and environmental advantages in promoting a host of measures relating to energy conservation, demand side management and acceleration of renewable energy applications. While the conclusions may give one a sense of *deja vu*, having been suggested, at least in part and most often qualitatively, by various expert committees, the fact remains that little progress has been made towards translating the suggested measures into implementable action plans.

Again, the scenarios described in this report are striking as they present the aggregate impact of a number of measures, all of which may not appear to be of significance. Thus, Scenario VI puts forward the possibility of saving nearly 170 Mt in coal burning in the year 2011/12, with a small increase in petroleum product use of approximately 12 Mt. This, and the concomitant environmental benefits, could be achieved by an increase in costs, albeit of the energy system, of Rs 7 billion only (annualized).

Given the obvious attractiveness of following the more optimal energy paths defined earlier, the question that arises is: Why the large divergence between the obviously optimal choices, under the given circumstance and the actual path being followed? What needs to be done to steer development closer towards the optimal path?

The report presents both, broad policy measures as well as specific action plans that should be undertaken to move towards a more environmentally benign growth path. The major environmental issues arising out of the patterns of energy development being followed were broadly classified as deforestation/resource degradation, urban environment, ambient air quality, rehabilitation, quality of life and transnational impacts. The policy measures required for facilitating a more environmentally benign energy development path have been detailed under the broad heads of:

- integrated resource planning,
- promoting energy efficient appliances and equipment,
- clean technologies and energy products,
- recycling waste utilization,
- international environmental concerns, and
- institutional strengthening measures.

CHAPTER 1

Energy economy linkages in India—A macro view

Background

The economic reforms process, currently underway in India, would largely dictate the long-term development path of the country. The importance of the energy sector as an input to development is well known and this is an opportune time to evaluate the lessons learnt from the past, particularly in terms of sustainability issues, and analyse the energy and environmental implications of suggested economic growth patterns for the future.

Structure of the Indian economy

Indian economy has historically been developed as a mixed economy, dominated by the Public sector. As such, the structure and growth of the economy have been influenced significantly by the allocation of plan budgets across various sectors of the economy.

The initial planning periods were focussed on industrial growth in a conscious attempt to improve the infrastructural base of the economy with scant attention to the agricultural sector. By the early sixties, however, it was apparent that India was heading for a food crisis and the focus of planning shifted from industry to agriculture. With increased outlays, agricultural growth recovered with phenomenal increases in productivity, aided by the Green Revolution. The following table (Table 1.1) gives the Plan outlays for the industry, agriculture and services sectors, the contribution of each of these to the gross domestic product (GDP), and the sectoral growth rates over the Plan periods. Figure 1.1a shows the plan outlays for various sectors and Figure 1.1b shows the sectoral growth of real GDP for the agriculture, industry and services sectors at 1980/81 prices.

Table 1.1. Real growth rate during various Five Year Plans (per cent)

	Agriculture	Industry	Services
First Plan (1951–1956)	2.9	5.9	3.7
Second Plan (1956–1961)	3 2	6.4	4.6
Third Plan (1961–1966)	−0.5	6.8	5.0
Fourth Plan (1969–1974)	2.6	3.7	4.0
Fifth Plan (1974–1978)	3.4	6.3	5.5
Sixth Plan (1980–1985)	5.5	6.2	5.4
Seventh Plan (1985–1990)	3.4	6.5	7.4

In the Sixth Plan period (1980–85), a major redistributive change in the allocation of resources was visible which was oriented towards achieving a high growth rate for the economy. Recognizing the supply of electricity as a crucial input to economic growth, the

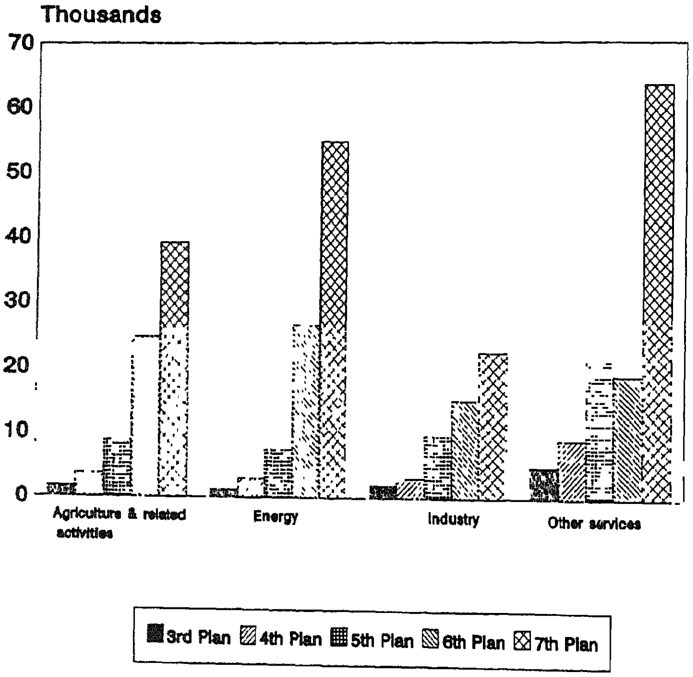


Figure 1.1a. Plan outlays for different sectors

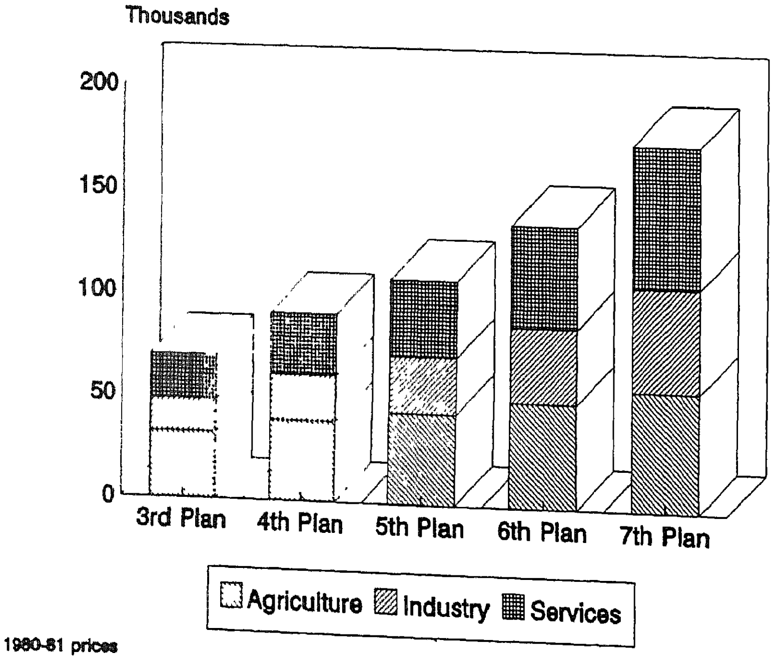


Figure 1.1b. Sectoral growth of real GDP

Plan allocation for the power sector increased dramatically from roughly 18% in the previous Plan periods to over 28% in this period. There was also much debate on the liberalization of the Indian economy and the role of the public sector started diminishing. The high allocation to the power sector continued during the Seventh Plan period with marginally higher allocations for agriculture and transport, and industry being increasingly left to fend for itself.

While India was largely an agrarian economy, with agriculture and allied activities contributing to nearly 60% of the total gdp at the time of independence, by the end of the Seventh Plan period, the share of agriculture in the gross domestic product was down to 32% while the share of industry had increased from 15% in 1950/51 to nearly 30%. The share of the services sector, particularly, transportation and communications, also increased significantly to meet the needs of an increasingly integrated domestic market and increased international trade.

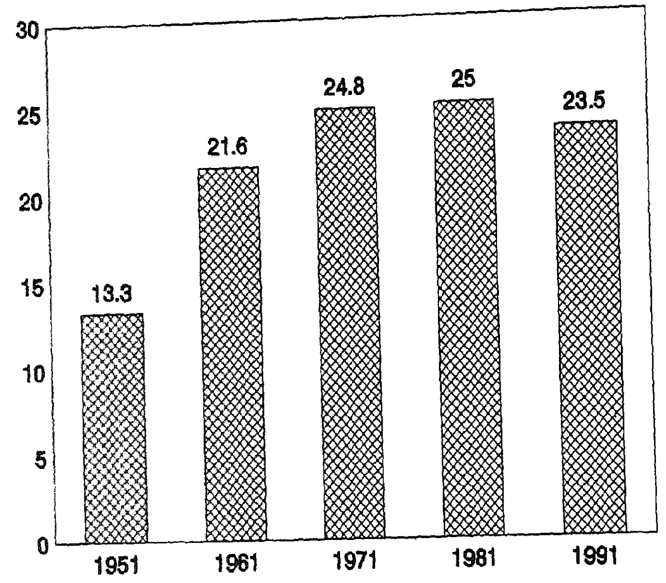
In terms of growth, over the period 1960/61–1992/93, agriculture had registered a cumulative annual growth rate of 2.3%, industry of 5.2%, transport, communications and trade of 5.2%, and the economy as a whole, of 4 per cent.

Structure of the population

India's population, largely dependent on agriculture, grew at an average annual rate of 2.15% over the period 1951–1991. However, the gross sown area over this period increased by a mere 0.8%. This, accompanied by a lack of developmental, and hence, employment generation activity in rural areas, resulted in a large-scale migration from rural to urban areas, thus increasing the share of urban population in the total from 17.3% in 1951 to 25.7% in 1991. Figure 1.2a shows the decadal growth of the population (per cent) and Figure 1.2b shows the rural-urban composition over the period 1951–1991.

The migration of labour from rural to urban areas, created its own set of problems—both economic and environmental. The larger towns and cities quite obviously holding a greater attraction in terms of probabilities of finding employment, attracted a large number of migrant workers. As such, most of the major cities in the country, including the metropolises, are estimated to have about 25–30% of the population living in slums. As a corollary to this magnetic attraction, there is a definite trend in moving towards larger and larger cities. This phenomenon also exists in rural areas where the number of larger villages is increasing albeit in a more subdued manner, primarily because the rural populations are tied to the land that they own or operate, thereby reducing their mobility.

With the increased work-related mobility of both rural and urban populations, on an average, per capita incomes went up from Rs 1483 to Rs 2134 in the period 1951–91 and



Source : Centre for Monitoring Indian Economy, Basic Statistics, India, August, 1994.

Figure 1.2a. Decadal population growth (%)

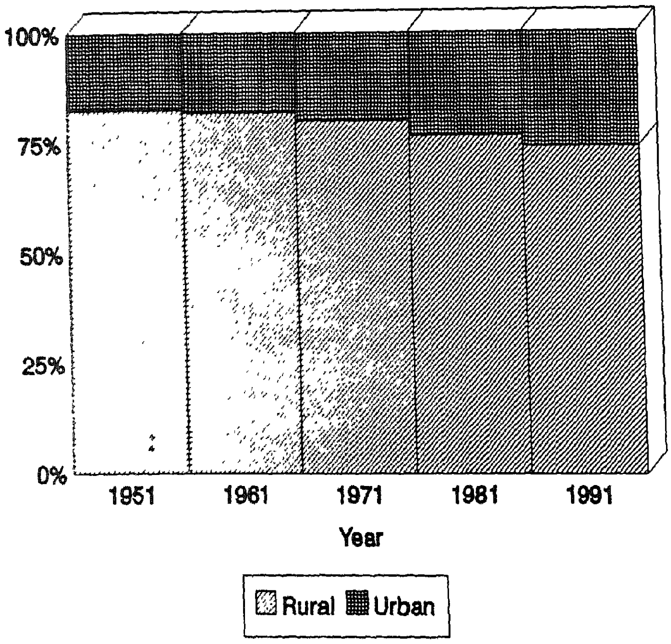


Figure 1.2b. Percentage share of rural and urban population

to Rs 2216 in 1992/93.[1] The percentage of population below the poverty line also decreasedostensibly from over 50% in 1973/74 to about 25% in 1989/90. However, hidden behind these aggregates, are growing income disparities, both between and within the urban and rural populations. The ratio between the value addition by an urban worker and a rural worker in 1970/71 was 2.76 whereas in 1980/81 this increased to 3.27. The differences in income levels across and within urban and rural areas as well as, the implications of structure and size on the existence of markets result in very different lifestyles and energy consumption patterns and hence environmental impacts.

Energy consumption growth—A macro picture

While the structural changes in the economy and the population were significant, leading to large increases in the consumption of commercial energy, the rural populations in the country despite various interventions, continue to depend heavily on biomass fuels. These fuels are estimated to account for around 40% of the total final energy consumption, and 90% of the energy consumption in rural areas, even today. However, the role of traditional fuels, in the national energy mix, is decreasing as they are being increasingly substituted by more efficient commercial fuels.

The overall consumption of commercial energy increased at an average annual rate of nearly 5% over the period 1972/73–1991/92, from 54–130 million tonne oil equivalent (Mtoe). However, the per capita consumption increased at a rate of 2.3% only from 96–148 kilograms oil equivalent (kgoe). This is still quite low, as against a world average of above 1500 kgoe per capita and even lower as compared to the averages for the high-income economies.

Economic growth, based on rapid industrialization and urbanization, is an important factor which contributed to this increase in energy consumption in India. The GDP for the Indian economy increased from Rs 9 04 260 million in 1970/71 to Rs 2 330 420[2] million in 1993/94 (at 1980/81 prices). The overall intensity of commercial energy consumption per unit of GDP increased, albeit marginally, from 54 kgoe per thousand rupees in 1970/71 to 60 kgoe per thousand rupees in 1988/89 (at 1980/81 prices) with significant fluctuations on a year-to-year basis (Figure 1.3).

In India, industry is a major energy consuming sector, comprising the manufacture and processing of a diverse mix of goods with varying degrees of technical sophistication and widely ranging energy intensities. The commercial energy intensity of industry declined from approximately 923.3 kgoe per thousand rupees value added (9233.2 kcal per rupees value added) to about 383.1 kgoe per 1000 rupees value added (3830.9 kcal/rupees value added) from the year 1974–1986. This can be explained by the changing structure of the industrial sector as also by energy conservation; while the former was predominantly responsible for the decline in the 1970s to mid-1980s; increasing awareness about the scope for energy efficiency has been prominent in the post 1986/87 period.

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[1] Source: Basic Statistics Relating to the Indian Economy, August 1994, Centre for Monitoring Indian Economy, Pvt Ltd

[2] Quick estimates

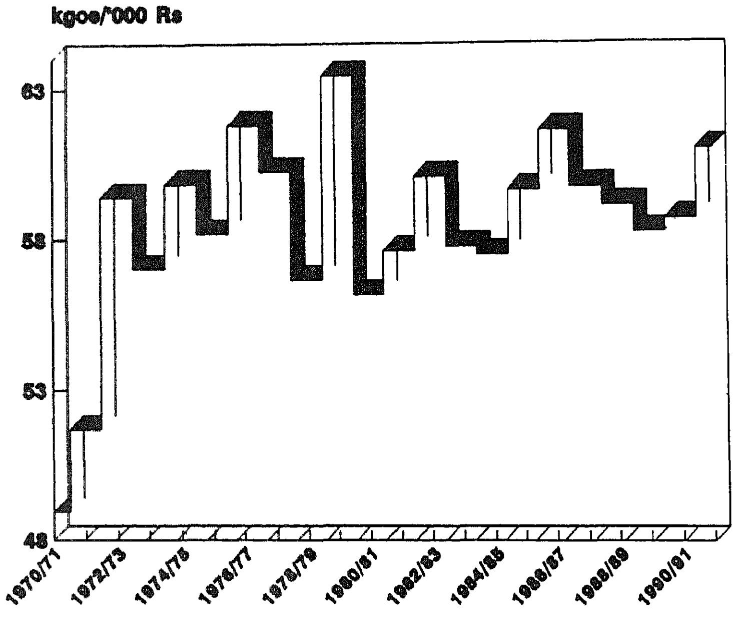

Figure 1.3. Commercial energy intensity

The period following the two oil shocks in 1973/74 and 1978/79, was characterized by a greater substitution of coal for petroleum products in industries as well as a shift from energy-intensive industries (namely iron and steel, aluminium, textiles), to non-energy-intensive industries (such as electrical and non-electrical machinery, automobile manufacturing, pulp and paper, food processing etc.). It can be seen from Figure 1.3, that a major downturn in energy intensity occurred in the period 1978/79–1980/81.

As in case of the industrial sector, the commercial energy intensity in the transport sector also declined from a level of 419 kgoe per thousand rupees to 303 kgoe per thousand rupees of value added. The percentage decline in case of the transport sector was slightly higher than that in the industrial sector. In the transport sector, railways experienced an increase in the overall energy efficiency since 1970, largely due to a major shift in the mix of locomotives from steam to diesel and electric ones.

Explaining the decline in energy consumption intensity in the transport sector is complex, particularly because there has been a distinct shift from railways to movement by road in the past two decades. The road transport sector is inherently more energy-intensive than rail transport. Thus, several other factors must have contributed to the gradual decline of overall transport intensity.

In the case of road transport, structural changes characterized by an increasing population of two- and three-wheelers as against cars and taxis, and more energy efficient models of the latter have jointly contributed to lowering of energy intensity. However, a more probable explanation is that the value addition in the road transport sector more than offsets the higher energy intensity when compared to the railways.

As opposed to a reduction in energy intensity in the industrial and transport sectors, agriculture increased its dependence on inputs of commercial energy. The intensity of energy use went up steadily from 2.33 kgoe per thousand rupees in 1972/73 to 3.88 in 1979/80. Thereafter, it increased from 4.03 in 1984/85 to 6.39 in 1988/89. The need to increase yield from unit land resulted in a wider adoption of multiple cropping practices with an increased use of high-yielding varieties. In fact, the intensity of this sector may be higher than what the above data suggests, as there are no official (published) estimates of petroleum products used for underground irrigation and land preparation.

In context of the above discussion on energy intensities, the following paragraphs examine the overall energy-GDP elasticity for the period 1970/71–1990/91. While for a study of the energy consumption response of the economy it may be useful to analyse the energy price elasticities, past experience has shown that it is the availability considerations rather than price levels, which have been the important determinants of energy demand. Price elasticities lose their meaning in an energy scarcity situation as prevalent in India.

The elasticity estimates for the period 1970/71–1988/89 are presented in Table 1.2.

Table 1.2. Energy-GDP elasticity for India

1970/71–1980/81	1.15
1980/81–1988/89	1.17
1970/71–1988/89	1.20
1970/71–1973/74	4.38
1973/74–1979/80	1.52
1979/80–1984/85	0.47
1984/85–1988/89	1.16

These estimates may be treated with caution because: (i) they do not capture the declining share of traditional fuels in the energy consumption mix and as such, the elasticity estimate based on commercial energy alone tends to be an overestimate, and (ii) commercial energy consumption has shifted to more efficient fuels, which implies that aggregation of fuels on their intrinsic energy content rather than useful energy content, tends to underestimate the GDP elasticity.

Despite the above limitations, the elasticity estimates do present some useful indications. For instance, for every 1 per cent increase in GDP before the first oil price shock, energy consumed increased by over 4 per cent (1970/71–1973/74 elasticity estimate was 4.38). Such high elasticities are typical of developing countries in the pre-1973 era of soft energy prices, when energy economy and conservation were not a major concern. Thereafter, for the period 1973/74–1979/80 there was a drop to 1.5 as the share of the output of certain major energy-intensive sectors of the economy decreased and oil prices increased sharply. During the first half of the 1980s (1979/80–1984/85), the elasticity declined to 0.47 as the rate of growth of energy-consuming sectors was only 2.9% per annum for the six-year period and GDP grew at 5.9% per annum. This could be explained by the new imperatives for energy conservation in the light of the second oil price shock. Beyond 1984/85, however, when oil prices in the international market became soft and eventually declined, the energy-GDP elasticity increased to about 1.2 in the period 1984/85–1988/89.

Although the energy-GDP elasticity has decreased considerably since the early 1970s, it is very high as compared to that of developed economies where it is reported to be less than unity. The relatively high levels in India, may relate to the fact that its per capita commercial energy consumption levels are still very low, and the use of traditional fuels is still being substituted by commercial energy forms. Also, the inefficient use of energy in a variety of enduses cannot be ignored.

CHAPTER 2

Energy reserves and production

Energy resources

How rich is India's endowment of energy resources? How effectively are these being utilized?

Although India is relatively well endowed with both exhaustible and renewable energy resources, it also has about 16% of the world's population to take care of. Coal is the major exhaustible energy resource of the country, and has a life expectancy of over 200 years. However, on a per capita basis, coal resources would still be well below the world average. As with other resources, this cannot be construed as a resource shortage *per se* but signifies an unequal distribution of resources in the world.

Table 2.1 presents the proven energy resources in India and the total world resources.

Table 2.1. Proven energy resources

	Unit	*India*	*World*	*India as a % of the world*
Coal	Bt[a]	59.0	1078.1	5.47
Oil	Bbbl[b]	5.91	1009.2	0.59
Natural gas	Tcu.m[c]	0.73	119.2	0.61
Hydropower	MW[d]	94.0	n.a.	—

[a]billion tonne [b]billion barrels [c]tera cubic metres [d]megawatts

Sources

1/ World Energy Council (WEC), 1992

2/ British Petroleum (BP), 1991

Coal

Identified deposits of coal occur in 44 major coalfields located in the states of West Bengal, Bihar, Uttar Pradesh, Madhya Pradesh, Orissa and Andhra Pradesh. Minor deposits are also found in the north-eastern states of Meghalaya and Assam. According to the most recent assessment, the total geological reserves of coal stand at 192.4 Bt [Geological Survey of India (GSI) 1992], of which more than 90% are found in the central and eastern parts of the country. The geographical concentration of this resource makes it necessary to transport it over long distances to the consuming centres scattered all over India.

Coal resources have generally been classified according to the extent of exploration, degree of certainty, convenience of mining, and quality in use. The entire geological stock is categorized as proven, indicated, and inferred, depending upon the extent of exploration. The exploratory efforts aim at converting inferred reserves to indicated reserves and finally, to proven reserves, apart from establishing new coal-bearing locations.

Depending upon the degree of certainty, total reserves are classified as mineable and recoverable, which are related to the probability of extracting coal from different seams (Table 2.2). Some quantity of coal cannot be extracted due to geophysical constraints imposed by underground fires, water, townships, railway lines and roads and the rest are called mineable reserves. The international practice is to take 90% of proven, 65% of indicated, and 30% of inferred reserves as mineable.

The salient features of coal reserves are:

- about 63% of total coal reserves occur within a depth of 300 m and 26% occur in the depth range 300–600 m. Only about 10% reserves occur beyond 600 m, in deep coal basins like the Jharia and Raniganj coalfields,
- coking coal reserves are only 15% of the total coal reserves,
- of the reserves of non-coking coal, only 12% are of superior grade, and
- bulk of the coal reserves (73%) are inferior grade non-coking coal occurring in thick interbanded seams and located in coalfields like Singrauli, Talcher, North Karanpura, Rajmahal, Ib Valley and Korba, etc.

Table 2.2. Geological, mineable and recoverable reserves of coal as on January 1, 1991 (Bt)

	Geological	*Mineable (up to 600 m)*	*Recoverable (up to 600 m)*
Prime coking	5.3	2.2	1.0
Medium coking and blendable	23.9	43.1	7.5
Non-coking	163.2	125.7	60.3
Total	192.4	171.0	68.8

Sources

1/ Planning Commission, Government of India

2/ Geological Survey of India (GSI), 1992

Oil and gas

The reserves of oil and gas that fall in the recoverable category are only around 5.88 Bt, as of January 1991. The total area of sedimentary basins in India is of the order of 1.72 million km^2, comprising 1.4 million km^2 onshore, and 0.32 million km^2 offshore within the 200 m isobath line. This has a total of 26 basins, 13 of which are of geological interest. The prognosticated resources of oil and oil equivalent of gas were estimated at 5.6 Bt in 1964, increased to 12.8 Bt in 1975 and to 15 Bt in 1982. The most recent estimate reported by the Ministry of Petroleum and Natural Gas in 1992 stood at 21.31 Bt of oil and oil equivalent of gas.

Figure 2.1 presents trends in reserve build-up over time. The total balance recoverable reserves of oil and gas have grown from about 300 Mt of oil equivalent (Mtoe) in 1970 to over 1400 Mtoe in 1990. The balance recoverable reserves picked up considerably after 1976, due to the large discovery at Bombay High in that year.

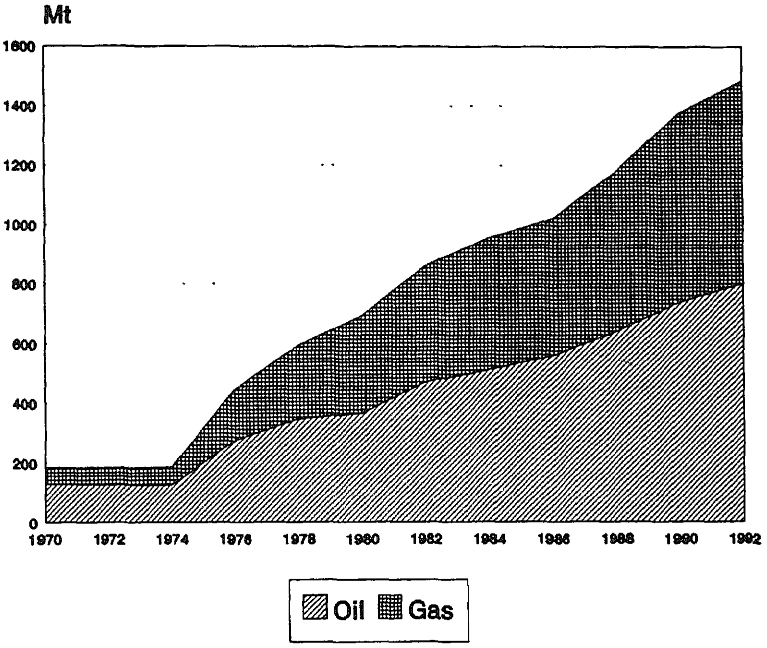

Figure 2.1. Balance recoverable reserves of oil and gas

While the exploratory activity of the public sector oil exploration and production companies—Oil and Natural Gas Commission[1] (ONGC) and Oil India Limited (OIL)—expanded, particularly in offshore areas, they continue to fall short of their targets, mainly due to delays in supply of rigs, and also due to adverse climatic conditions (Table 2.3).

Power

The annual hydro-electric potential in the country is placed at 600 terawatt hours (TWh) of which more than three-fourths is confined to the northern and north-eastern region. A regional break-up of the hydro potential, as per the preliminary estimates available is given in Table 2.4.

Apart from the above data, the Central Electricity Authority (CEA) had undertaken extensive studies to identify the sites for the development of pumped storage schemes. The results indicate that the 56 sites identified thus far offer a potential of 94 000 megawatts (MW), of which only 20% (18 800 MW) had been developed until 1990/91.

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[1] now Oil and Natural Gas Corporation

Table 2.3. Proved and indicated balance recoverable reserves of crude oil and natural gas (State-wise)

	Gujarat	*Assam*	*Rajas*	*Total*	*Bombay*	*Grand*
1965/66						
Oil	62.7	90.3	—	153.0	—	153.0
Natural gas	23.1	40.1	—	63.2	—	63.2
1970/71						
Oil	51.1	62.7	—	113.8	—	113.8
Natural gas	18.8	43.5	—	62.3	—	62.3
1975/76						
Oil	45.8	82.0	—	127.8	147.7	275.5
Natural gas	16.4	61.4	0.4	78.2	106.6	184.8
1980/81						
Oil	51.5	89.0[1]	—	140.5	328 3	468.8
Natural gas	16.0	65.22	0.4	81.6	329.0	410.6
1985/86						
Oil	98.6	13.8[1]	—	212.4	345.5	557.9
Natural gas	27.0	91.8	0.5	119.3	377.7	497.0
1990/91						
Oil	158.3	156.2[1]	—	314.5	491.7	806.2
Natural gas	93.4	151.7[2]	1.2	246 3	483.5	729.8

[1] includes crude oil reserves in Nagaland, Tamil Nadu and Andhra Pradesh [2] includes natural gas reserves in Nagaland, Tripura, Tamil Nadu, Arunachal Pradesh and Andhra Pradesh

Note For the Assam Oil Company and Oil India Limited the data relate to 1st January of each year while for ONGC, the data relate to 1st October up to 1974 and 1st January of each year thereafter

Source Government of India (GOI), 1991/92

Table 2.4. Hydro power potential in TWh

Region	**Potential**
Northern	225 0
Western	31.4
Southern	61 8
Eastern	42 5
North-eastern	239 3
All India	600 0

Source GOI, 1992

There exists approximately another 5000 MW of potential, for exploitation through mini/micro hydel schemes along nearly 1000 sites on existing dams, canal drops etc. About half of these are concentrated in the southern states (Tamil Nadu, Andhra Pradesh and Karnataka), where the potential was placed at 2000 gigawatt hours (GWh) of energy per annum (GOI, 1992).

Energy supply

Commercial sources of energy (coal, oil, natural gas), account for nearly 60% of the total energy supplies while non-commercial sources (primary fuelwood), make up the balance. Given the large resources of coal, it is obvious that coal dominates the commercial energy supply profile.

Coal

The establishment of the National Coal Development Corporation in 1956 was the first step in the planned development of the coal industry. However, it was not until the nationalization of the coking coal mines in 1971 and of non-coking coal mines in 1973, that a comprehensive programme for the development of coal mines was launched. To ensure a sustained and planned development of all facets of the coal industry, massive investments to the tune of about Rs 160 billion (16 000 crores) have been made since its nationalization, in opening up of new mines, reorganization of existing mines, and development of the associated infrastructure. Coal production has registered an annual growth rate of about 6 per cent during the last 2 decades, steadily increasing from a level of 77 million tonne (Mt) in 1972/73 to about 246 Mt in 1993/94 (80 Mt and 264 Mt respectively, if lignite is included).

However, it should be mentioned here that this magnitude of increase in the production of coal was feasible due to the greater emphasis given to opencast (OC) mining methods. Opencast mines which contributed about 28% of the total production at the time of nationalization (1973) increased their share to about 70% in 1993/94. The major factors in favour of opencast mines are: a shorter gestation period, high recovery and safety, and a lower cost of production. However, most of the coal produced from OC mines is of an inferior grade mainly suitable for power generation.

The details of technology-wise and type-wise production are given in Table 2.5 and Table 2.6.

Only 21% of the total coal produced in India has coking properties and is largely used for steel manufacturing and in foundries. The non-coking coal is mostly used for power generation and steam generation by industries.

Table 2.5. Technology-wise coal production (Mt)

Year	*Underground*	*Opencast*	*Total*
1970/71	58.2	14.7	72.9
	(79.9%)	(20.1%)	
1980/81	73.3	40.7	114.0
	(64.2%)	(35.7%)	
1992/93	72.7	165.6	238.3
	(30.5%)	(69.5%)	

Note. Figures in brackets indicate percentage share

Table 2.6. Type-wise coal production (Mt)

Year	*Coking*	*Non-coking*	*Total*
1970/71	17.8	55.1	72.9
	(24.4%)	(75.6%)	
1980/81	26.8	87.2	114.0
	(23.6%)	(76.4%)	
1992/93	45.4	192.9	238.3
	(19.0%)	(81.0%)	

Note Figures in brackets indicate percentage share

The problems afflicting the Indian coal industry are:

- inappropriate estimation of production targets leading to accumulation of stocks at coalfields,
- constraints in the movement of coal from the Eastern region (which is endowed with this resource) to other parts of the country,
- growing dependence on imports of coking coal for steel plants as overall availability of this is declining, and
- issues related to economics of beneficiation of non-coking coal for use in power stations remains unresolved.

Coal washeries. Steel plants in India are designed to use coking coal with 17±0.5% ash for producing metallurgical coke. As such, most of the coal being supplied to the steel plants is washed. For this purpose there are 21 coal washeries with a total throughput capacity of 34.2 tonnes per annum (t/a), which includes both prime and medium coking coal.

Two coking coal washeries are under construction, one for medium coking coal (2.6 million tonnes per annum [Mt/a]) and the other for prime coking coal (2.5 Mt/a). The details of performance of washeries are given in Table 2.7.

Table 2.7. Performance of washeries

Item	*1984/85*	*1992/93*
Operable capacity (Mt)	30.6	34.2
Raw coal feed (Mt)	20.2	22.5
Capacity utilization (%)	66.0	65.8
Clean coal production (Mt)	11.8	12.8
Yield (%)	58.4	56.9
Middling production (Mt)	5.3	6.5

A technical group, set up by the Government has recently examined the entire coking coal sçenario in India and has recommended an Action Plan for reducing dependence on imports. The total demand of coking coal of the steel plants (as fed to ovens) would increase to 22.80 Mt [for Steel Authority of India Limited [SAIL] and Vishakapatnam/Vizag Steel Plant (VSP) only] by the year 2001/02. The domestic availability can be increased through implementation of the recommended action plan to about 20.7 Mt (at 16.86% ash) against the present availability of about 12 Mt (at average ash content of 19.3%).

There are no washeries for washing non-coking coal as yet in the country. In 1988, the Ronghe Committee appointed by the Planning Commission had recommended that coal—to be supplied to new power stations located more than 1000 km away from the coalfields—should be beneficiated to reduce the ash content to about 34%. Based on this recommendation, the Government has sanctioned five non-coking coal washeries with a total capacity of 24 Mt/a. One washery of 6.5 Mt/a capacity is under construction, and the others are in the planning stage.

Some factors in favour of washing non-coking coal are:

- better quality coal reserves are only about 25% of the total reserves; the balance 75% are of poor quality and need to be beneficiated,
- increased mechanized mining, particularly opencast mining, has led to further deterioration in the quality of run-of-mine coal,
- majority of the coal deposits are situated in the eastern and central parts of the country, whereas the thermal power stations and other consumers are widely dispersed necessitating long distance transportation of coal,
- high cost of transportation of dirt along with coal and subsequent ash disposal adds to the cost and to the deterioration of the environment, and
- greater concern is expressed by consumers about consistency of quality and the size of coal for improving their performance and productivity.

Coal movement

Coal is transported by the railways, road and captive modes like the rail-based merry-go-round system, conveyor belts and aerial ropeways. In some cases, rail-cum-coastal shipment is also used for supplying coal to the consumers in southern India. Railways are the major mode of transport of coal in the country. Given the concentration of coal in the eastern and central parts of India, many coal carrying railway routes are already saturated or reaching saturation levels. The details of mode-wise coal movement are given in Table 2.8.

Oil and natural gas

India is a net oil importing country, whose oil import bill is seen to be increasing every year. Historically, the rising oil import bill was the focus of concern due to the pressure it placed on scarce foreign exchange resources. However, the recent economic reforms in the country and the full convertibility of the rupee have changed the perspective on oil imports radically.

Table 2.8. Mode-wise coal movement in 1992/93 (Mt)

Mode	*1987/88*	*1992/93*
Rail	114.9	142.7
	(64%)	(55%)
Road	42.2	50.6
	(24%)	(19%)
Belt/ropeway	4.3	5 4
	(2%)	(2%)
MGR	17.1	61.7
	(10%)	(24%)
Total	178.5	260.4

Note Figures in brackets indicate percentage share

With acceleration in exploratory and developmental drilling, there has been a substantial increase in the production of crude oil and natural gas at least until 1985/86. Production of crude oil rose from 6.8 Mt in 1970/71 to 33 Mt in 1990/91. Natural gas production, on the other hand has increased significantly from 1445–17 998 million cubic metres (Mcu.m) over the same period (Table 2.9 and Table 2.10).

Table 2.9. Commodity balance of petroleum and petroleum products (Mt)

	1970/71	*1975/76*	*1980/81*	*1985/86*	*1990/91*	*1993/94*
Crude						
Refinery throughput	18.4	22.3	25.8	42 9	51.8	53.4
Domestic production	6.8	8.4	10.5	30 2	33	27.0
a Onshore	6.8	8.4	5.5	9 4	11 8	11.7
b. Offshore	—	—	5.0	20.8	21.2	15.3
Net Imports	11.7	13.6	16.2	14 6	20.7	30.8
Petroleum products						
Domestic production	17.1	20 9	24.1	39.9	48 6	51.1
a Light distillates	3.0	3.6	4.1	8.3	9 8	—
b Middle distillates	8.6	10.8	12.1	21 6	26.6	—
c Heavy ends	5.5	6.4	7.9	10	12.2	—
Net imports	0 8	2	7.3	1.9	6 5	8.1

Source Indian Petroleum & Petrochemical Statistics, Various Issues

This increase has largely been due to an accelerated production from the Bombay High offshore basin. In 1990/91, Bombay High accounted for 64% of crude oil produced in the country and 78% of gross natural gas (associated and free) production.

The trends in reserves to production (R/P) ratio over the last twenty years for oil and gas are shown in Figure 2.2. As seen in the figure, the R/P ratio for natural gas, though declining over the years, is still at a higher level than for crude oil. This clearly brings out the possibility of a somewhat higher rate of production of natural gas than at present. The R/P ratio for crude oil has remained by and large the same during the latter

Table 2.10. Gross and net production of natural gas (Bcu.m)[1]

	1970/71	*1975/76*	*1980/81*	*1985/86*	*1990/91*[2]
Gross production	1445	2368	2358	8134	17998
Onshore	1445	2368	1685	2954	3916
Offshore	—	—	673	5180	14082
Gas re-injected	36	162	67	66	102
Onshore	36	162	67	66	102
Offshore	—	—	—	—	—
Flared	762	1082	769	3118	5130
Onshore	762	1082	403	1005	1083
Offshore	—	—	366	2113	4047
Net production	647	1124	1522	4950	12766
Onshore	647	1124	1215	1883	2731
Onshore	0	0	307	3067	10035

[1]billion cubic metre [2]provisional
Source. GOI, 1991/92

part of the 1980s. The ratio had gone up in the early 1990s due to planned containment of Bombay High production. Going by the present trends, it may not be possible to bring down the ratio below 20/25 years. Significant increases in oil production in the years to come will therefore depend upon the rate of reserve accretion.

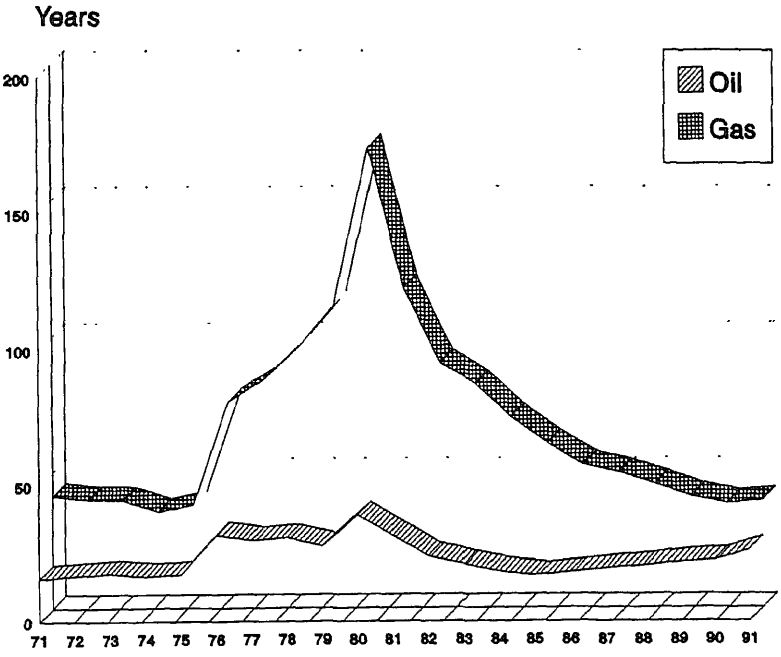

Figure 2.2. Reserves to production ratio

However, the rapid strides in crude oil production witnessed in the first half of the 1980s seem to have tapered off.

The main issues that need to be examined in this sector are:

- constancy in oil production due to flogging of wells in the initial rush of enthusiasm,
- immediate attention to optimize the cost of producing oil through efficient management of production by:
  - liquidating sick wells,
  - ensuring that development wells which have been drilled are connected for production,
  - giving the enhanced oil recovery schemes a time dimension,
  - development of offshore marginal fields, and
- foreign exchange requirements and the sources for development of already discovered oil and gas fields.

In addition, one needs to rationalize the production profile from the refineries to meet the growing demand for middle distillates. In fact, a suitable mix of imports of crude and petroleum products needs to be given priority and in light of this, the expansion of current, and the establishment of new refineries, needs to be optimized.

The supply of natural gas on the other hand, has been constrained by the lack of downstream facilities for its utilization. Although gross natural gas production was 17 998 Mcu.m, net production was only 12 766 Mcu.m. About 29% of the gas was flared. There is very little flexibility in reducing the production of associated gases which in effect, means limiting oil production. However, in this sector, two measures that need to be introduced are:

- reverting to zero flaring except where flaring due to technical reasons cannot be avoided,
- tying up time-bound utilization of gas by signing commercial contracts in advance,

Status of Indian refineries

There are presently 13 refineries operating in India, all of which are Public Sector Enterprises (PSE), and come under the administrative control of the Ministry of Petroleum and Natural Gas. Since the early seventies, refining capacity has increased in line with the rising demand for petroleum products. Refinery production has increased nearly three-fold from 17.1 Mt in 1970/71 to over 48 Mt in 1990/91. Nevertheless, the total output from refineries has always remained less than the demand for these products.

The capacity utilization trend of these refineries is illustrated in Figure 2.3. In 1990/91, 7 refineries operated at above 100% capacity utilization, while the rest operated at over 75%.

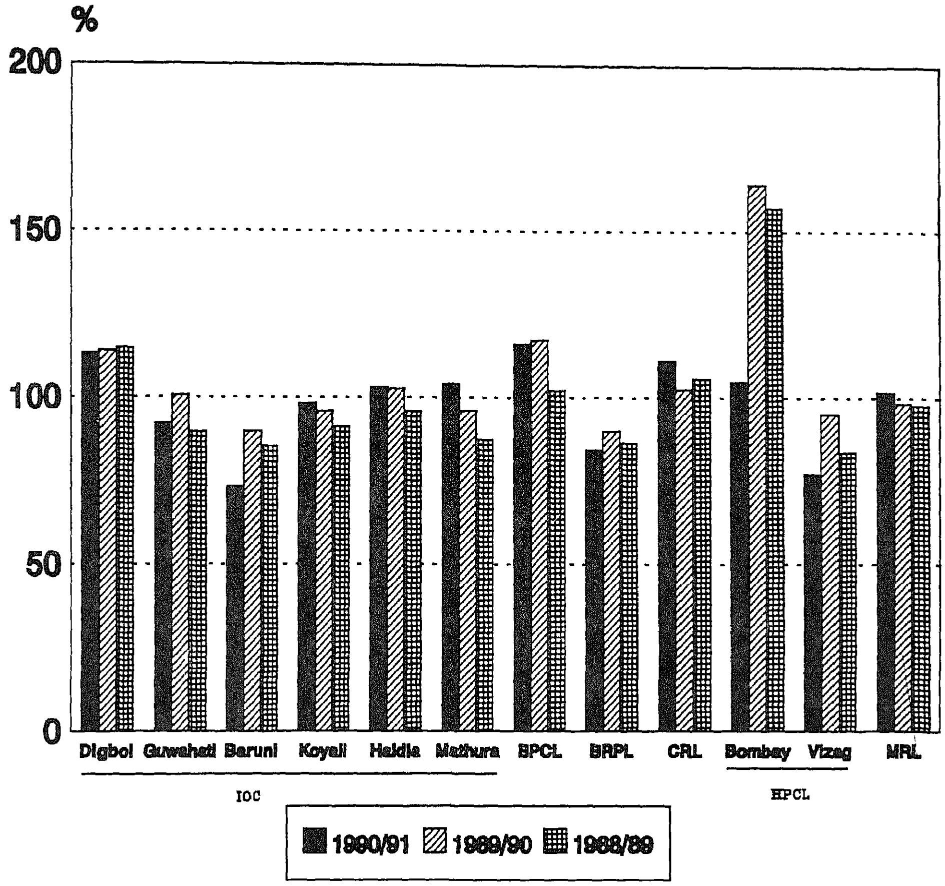

Figure 2.3. Refinery capacity utilization

Power

The power sector has experienced fairly high rates of growth since independence due to large investments made by the government in the successive Plans (Table 2.11). However,

Table 2.11. Annual rate of growth of installed capacity (%)

Period	*Thermal*	*Hydro*	*Total*
1950/51–1960/61	9.1	13.1	10.5
1960/61–1970/71	11.8	12.8	12.2
1970/71–1980/81	8.2	6.3	7.4
1980/81–1990/91	9.7	4.6	7.1
1950/51–1990/91	9.7	9.1	9.5

Source. Centre for Monitoring Indian Economy Pvt. Ltd. (CMIE), 1991 the power industry has been unable to fulfil the primary obligation of ensuring adequate power supply to the consumers and the quality of supply has been poor as well. Consequently, both energy and peak shortages of varying degrees are prevalent in various parts of the country. During 1991/92, the all India peak and energy deficits were 17.7% and 8.5% respectively.

The generating capacity in India comprises a mix of hydro, coal-based thermal, oil-fired thermal, gas, and nuclear plants. The different mix of generating capacities is presented in Figure 2.4. Installed utility capacity increased at a rate of 9.5% per annum during the period 1950/51–1990/91, and was 76 718 MW in 1993/94. Until the mid-1960s, power development was guided by the basic objective of developing hydel projects and filling in the gaps by thermal capacity and, as such, its share in the total installed capacity increased from 32.6% in 1950 to 45.6% by the end of the Third plan (1960–65).

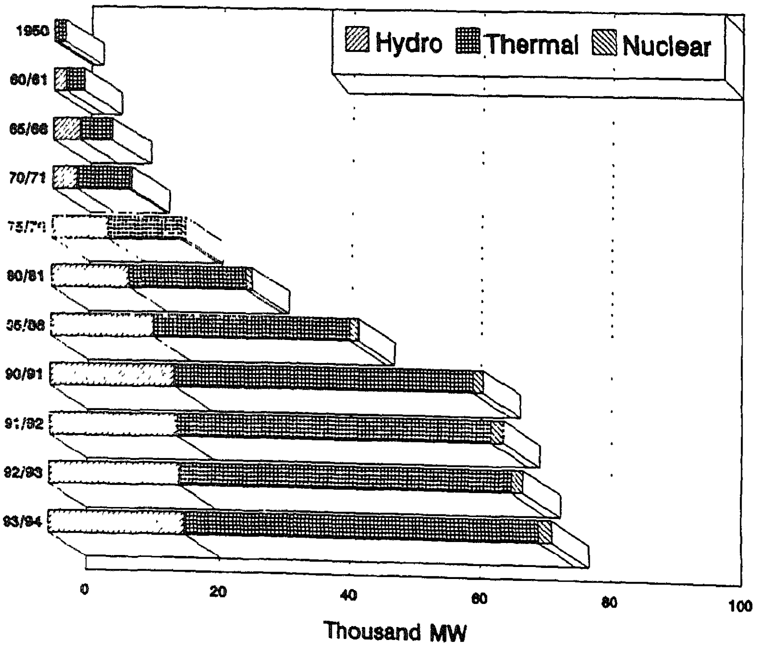

Figure 2.4. Installed capacity mix of utilities in India

However, since the early seventies, the hydro-thermal capacity mix has changed significantly, with the share of hydro capacity in total capacity declining from 43% in 1970/71 to 28% in 1991/92.

One of the basic reasons for a decline in the share of hydro capacity is the augmentation of thermal capacity to produce power in a shorter time period to match the rapidly increasing demand for electricity. Hydro development also lagged behind due to interstate disputes on sharing of water, rising costs, inadequate funding, delays in decision-making regarding land acquisition, non-standardization of unit size and plant design, inadequacies in construction management, contractual problems, and environmental aspects.

However, given the Indian energy situation, characterized by severe peaking shortages, it is necessary to restore confidence in hydro development, ensure availability of modern technology for investigation and construction of hydro projects, rationally view the concerns of environmentalists and carefully select some major sites for early development. The share of hydro power in the overall mix of capacity must be improved from the present level of 28% to at least 34% over the next fifteen years. Further, the possibilities of developing hydro resources by interacting with neighbouring countries such as Nepal and Bhutan needs to be explored.

Coal-based thermal power-generating capacity of the country as on 31st March 1994 was 54 300 MW. Technological developments and resultant economies of scale have seen an increase in the size of generating units. Till 1960, the largest size in use was a set of 90 MW, but now 210 MW and 500 MW sets have become common. Larger generating units have lower capital costs and lower operating costs due to higher efficiencies in heat utilization.

In addition to the choice of the type of power stations, their location is also very important. Earlier, the power stations were constructed closer to the load centres while today the emphasis has shifted to pithead locations, as moving large quantities of coal from the pit-head to a plant close to the load centre poses formidable operational problems, including that of heavy investments in the railway system. Excessive concentration of power plants at pit-heads too, will have serious environmental consequences and, therefore, the location of the power station must be decided on the basis of economic as well as environmental factors.

The nuclear power programme in India has not taken off as yet. Presently, about 2000 MW of nuclear capacity is installed in northern, western and southern regions, accounting for only 2.6% of the installed capacity. Five more units of 235 MW each are under construction, and the Department of Atomic Energy plans to install 5000 MW of nuclear capacity by the turn of the century. This targeted capacity, however, may not be achievable in light of the various technical and financial constraints. Long-term waste management and the eventual decommissioning of plants will be the two key concerns in the development of this sector.

In line with additions to installed capacity, gross generation in public utilities also increased rapidly from 5106 gigawatt hours (GWh) in 1950 to 323 500 GWh in 1993/94, registering a growth rate of 10.1% per annum (Table 2.12). Nuclear generation accounted for 2.5–2.7% of the gross utility generation. Owing to poor hydro development and prevailing peak power deficits, coal-fired thermal power units are often used for meeting peak loads. Since the start-up time for a coal-fired thermal power unit is four to five hours, these units have to continue generating at part load conditions during the night hours (when the demand is low), and this reduces their overall efficiency.

Table 2.12. Annual rate of growth of gross generation (%)

Period	*Thermal*	*Hydro*	*Total*
1950/51–1960/61	13.4	12.0	12.7
1960/61–1970/71	12.9	12.4	12.7
1970/71–1980/81	7.7	6 3	7.2
1980/81–1990/91	11.6	4 4	9.1
1950/51–1993/94	11.2	8.0	10.1

Source. CMIE, 1991

Plant performance

The average plant load factor (PLF) of thermal power stations in India is less than 60% (Table 2.13). The performance of 500 MW and 200 MW units has been satisfactory and their PLF is higher than the national average. The target group for improvement in generation from thermal units is 120/140 MW and below. Most of these units have already logged more than 100 000 running hours and their performance can only be improved through a long-term rehabilitation programme.

Table 2.13. Performance of thermal power stations during 1991/92 (%)

Region	*PLF*	*Planned maintenance*	*Forced outages*	*Plant availability*
Northern	58 12	10.10	17.04	72.86
Western	59 59	9 98	11 78	78.24
Southern	60 77	12 31	12.42	75.27
Eastern	37 29	19 17	22 41	58 42
North-eastern	25 48	18 36	34.39	47 25
All India	55 50	12.01	15.19	72 80

Source Central Electricity Authority (CEA), 1991/92

There is a significant difference between the performance of the thermal units in the private sector, central sector, and the state sector. In 1991/92, while the thermal stations operated by private utilities and central sector utilities, achieved an average PLF of 57% and 64% respectively, the corresponding figure for State Electricity Boards (SEbs) was 51% (Table 2.14). One of the reasons for a high PLF of NTPC owned power stations is the fact that all the units are of 200/500 MW capacity, and are relatively new. On the other hand, SEBs have a large number of small generating units and a good number of them are quite old and worn out.

The inadequate attention to planned maintenance inevitably results in increased forced outage rates of thermal units. During 1991/92, the all India average forced outage

Table 2.14. Sector-wise plant load factor of thermal power stations

Sector	1983/84	1985/86	1989/90	1990/91	1991/92	1993/94
Central	54.8	61.9	62.2	58.1	64.1	69.8
Private	64.1	57.5	69.5	58.4	56.7	57.0
State	44.9	49.2	53.0	51.3	51.0	56.6
Total	47.9	52.4	56.2	53.8	55.5	61.0

Source. CMIE 1991 and CEA, 1991/92

of thermal power plants was 15.2%. Consequently, all India thermal plant availability was only 73%. The percentage of total forced outage losses is given in Table 2.15.

Table 2.15. Percentage of total forced outage losses

Cause of outage	1985/86	1986/87	1987/88	1988/89	1989/90	1990/91	1991/92
Boiler	38.05	31.61	33.70	39.29	35.46	31.65	35.60
Turbine	11.50	26.00	23.12	23.53	14.70	13.80	14.95
Generator	23.72	20.00	18.19	10.76	21.29	18.37	8.45
Others	26.73	22.39	24.99	26.42	28.55	63.82	59.00

Source. CEA, 1992/93

The quality of coal available to the thermal power stations has declined considerably; the average calorific value of steam grade coal received at the power stations being about 4600 kcal/kg in 1975/76 and 3800–4100 kcal/kg since 1985/86. A large number of collieries are not able to supply their declared grade of coal and the share of low-grade coal (E, F and G) received for power generation has been increasing (Table 2.16).

Table 2.16. Quality of coal received at thermal power stations

Year	Average calorific value (kcal/kg)	Percentage receipt of coal in various grades						% of (E+F+G) grade
		B	C	D	E	F	G	
1985/86	4217	1.7	1.6	19.8	26.9	41.2	8.8	76.9
1986/87	4075	1.5	1.3	17.7	20.1	48.6	10.8	79.5
1987/88	3800	1.3	1.1	20.2	27.0	41.4	9.0	77.4
1988/89	4179	1.13	0.04	15.1	28.5	49.7	5.5	83.7
1989/90	4176	1.0	1.1	13.2	35.5	41.3	7.9	84.7
1990/91	4198	1.03	0.04	12.59	27.83	51.88	6.63	86.34
1991/92	4032	0.80	–	23.7	22.3	39.80	13.40	75.50

Source. CEA, 1991/92

Poor quality of coal received at the power stations results in high specific coal consumption per unit of electricity generated and therefore higher emissions per unit of generation and increased problems of ash disposal. Typically, coal consumption ranges between 0.70–0.72 kg/kWh, as against the usual norm of 0.60–0.65 kg/kWh.

Additionally, with a deterioration in coal quality, increasing amounts of oil are required to be fed into the boiler. During 1991/92, specific secondary fuel oil consumption in the central sector and private utilities was 3.80 millilitres (ml)/kWh and 8.40 ml/kWh respectively while the state-owned power stations consumed 8.7 ml/kWh (Table 2.17). While 500 MW and 200/210 MW generating units recorded 4.4 ml/kWh and 7.1 ml/kWh of specific oil consumption, for smaller units (140/150, 120, 100/110, 60 MW) it ranged between 13–20 ml/kWh.

Table 2.17. Sector-wise secondary fuel oil consumption

Sector	*1985/86*	*1986/87*	*1987/88*	*1988/89*	*1989/90*	*1990/91*	*1991/9*
Central	9.0	6.4	7.6	6.4	5.7	4.9	3.8
State	16.0	14.3	11.6	11.8	11.3	9.2	8.7
Private	9.3	4.7	4.6	8.1	6.8	9.0	8.4
All India	13.9	12.0	10.5	10.0	9.2	7.7	6.8

Source. CEA, 1991/92

With a view to optimizing generation from various thermal power stations, a Retrofitting and Modernization (R & M) programme was launched in the country in September 1984. The programme mainly covers renovation and modernization of thermal generating units having ratings of 140 MW and below and also certain 200–210 MW units which were not giving satisfactory performance for the past 3–4 years. The programme under Phase-I covers 34 thermal power stations aggregating to a total capacity of 13 475 MW The objective is to improve the PLF from 46%–53% on an average of these units to generate additional 7000 GWh per year. Against these targets, benefits of 11 000 GWh, 10 800 GWh and 10 700 GWh were achieved during 1988/89, 1989/90 and 1990/91 respectively.

Transmission and distribution

The basic transmission and distribution (T & D) configuration today is a 400 kV network as the main and bulk transmission system in each region; 220 kV, 132 kV and 110 kV network as the main and support transmission systems in each state; 66 kV, 33 kV and 22 kV network as sub-transmission systems; 11 kV networks as primary distribution systems; and 400 V (three-phase) and 230 V networks as local distribution systems. The major emphasis hitherto has been to use Alternating Current (AC) technology. Higher voltage direct current (HVDC) technology is being introduced for back-to-back interconnection between the northern and western regional systems and also for the bulk transfer of power in the northern region. Till now, one HVDC line has been established between Singrauli and Dadri in the northern region for bulk transfer of power to the Delhi area from the Singrauli area in central India, where there is a concentration of pit-head super thermal power stations.

The total T & D networks expanded by about 6.3% per annum during the 1980s and generally, the investments in the T & D system have been of less than the desired levels. As a result, the generation levels of certain power stations (for example, Singrauli and Rihand Thermal Power Station in the northern region), had to be curtailed because not all the required 400 kV lines had been commissioned to evacuate the power generated and T & D losses in the utilities increased (Figure 2.5).

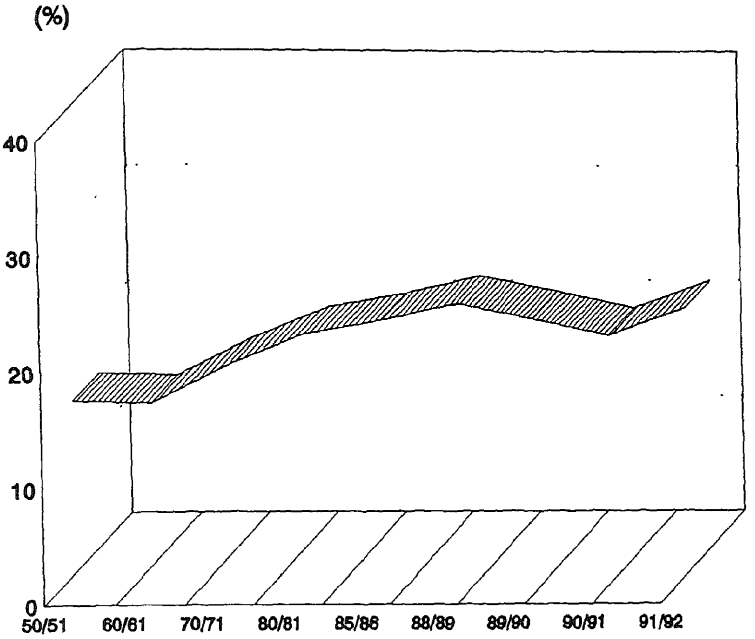

Figure 2.5. Transmission and distribution losses

The reasons for high T & D losses are:

- weak and inadequate sub-transmission and distribution system due to low priority having been given to these works as compared to the generation projects,
- large scale rural electrification programme undertaken in the country resulting in long lines and low power factor without strengthening the backup transmission and sub-transmission system,
- too many transformation stages, resulting in higher component of transformer losses,
- inadequate reactive compensation in the system, and
- improper load distribution, resulting in overloading of the system.

Apart from the technical losses, the incidence of non-technical losses is quite high in several utilities. For instance, according to a study conducted by Tata Energy Research Institute (TERI) for the Delhi Electricity Supply Undertaking (DESU), the total T & D losses of 22% comprise about 13% technical losses and 9% commercial losses. The prime reasons for the high non-technical losses include pilferage of electricity, faulty meters and unmetered supply.

Renewable energy

While renewable energy contributes to total energy consumption in a very small way, there are several arguments for employing renewable energy technologies (RETs) in defined situations in preference to conventional alternatives.

Sustainability. RETs depend on natural energy flows that are non-depletable (e.g., solar, wind, hydro, geothermal), and hence are *sustainable*. The sustainability of RETs also derives from the fact that in general, they are environmentally benign as compared to their conventional commercial energy counterparts. Solar, wind and micro/minihydel-based RETs have no polluting emissions and generate no wastes. Biomass-based devices, e.g., improved chulhas, are designed to be less polluting than traditional technology. Biogas plants not only have negligible polluting emissions as compared to the traditional practice of burning dung-cake but produce a useful resource, biogas slurry, which can be used as an organic fertilizer.

Reducing system losses. Conventional energy technologies often go through multiple conversions These multiple transformations involve energy loss at each stage, with the result that the final energy service obtained is a small fraction of the original primary energy used. On the other hand, several RETs involve either a single stage of conversion (e.g., biogas generation, photovoltaics), or simply a stage of concentration (e.g., solar cookers, water heaters). The energy supply from these RETs is thus directly matched to the enduse. As a result, system losses are substantially reduced improving the economics for renewables.

Decentralized applications. Several RETs are highly suited to decentralized applications (as opposed to centralized grid supply), because of the flexibility in scale that they offer. This has two important implications. First, since the number of devices that would be involved in countrywide use is extremely large, economies of scale in manufacture may be realized. Secondly, decentralized systems are comparatively easier to maintain than large centralized ones. Technologies like biogas can be promoted at the village or cluster-of-villages level and effectively managed locally.

Renewable energy programme in India. Although renewable energy technologies like biogas plants and improved cook-stoves had been disseminated in India since the late 1940s, the renewable energy programme started in right earnest only with the establishment of the Department of Non-conventional energy sources (DNES) in 1982. Till recently, RETs in India have been promoted through demonstration and R & D projects as well as large scale dissemination projects/programmes most of which were supported by government subsidies and financial incentives. Process of renewable energy programme in India is given in Table 2.18.

Table 2.18. Progress of renewable energy programme in India

Programme	*Cumulative achievement up to March 1994*
Family-size biogas plants	1 98 million nos
Improved cook-stoves	17 million nos
Solar thermal systems	277329 sq m (collector area)
Solar cookers	339 359 nos
PV[a] waterpumps	756 nos
PV power units	524 60 kWp
PV community lights/TV and community facilities	884 facilities
PV domestic lighting units	32 241 nos
PV street lights	28 674 nos
Windpumps	3017 nos
Windfarms	116 MW
Mini-micro hydro	110 MW
Biomass gasifiers/sterling engines	14 MW

[a] photovoltaic

Source. Ministry of Non-conventional Energy Sources (MNES), 1994

Though the above figures appear impressive, the renewable energy sector has contributed a very insignificant share to the overall energy mix in the economy. There have been two major reasons for this firstly, compared to the conventional energy sources, RETs have, except for a few biomass-based technologies, not been economically viable due to various technological and other constraints (Table 2.19).

The second reason for low penetration of renewables in India has been the low budgetary allocation for their promotion. Between 1980 and 1992, the cumulative government expenditure in the renewables sector totalled Rs 11.55 billion, as against Rs 812 billion in the power sector, Rs 335 billion in the petroleum sector, and Rs 158.5 billion in the coal sector. Even in the 8th Plan (1992–97), allocation for the renewables sector was just about 0.8% of the total funds allocated to the energy sector.

Table 2.19. Summary of the cost of energy from various technologies

Technology	Unit	Capital cost (Rs)	Useful life	Capital recovery factor	Annual capital cost	Recurring costs O & M(#)	Recurring costs Fuel	Total annual cost	Annual generation (*)	Cost of Energy
Centralized power generation										
Renewable Technologies										
Windfarm	kW	35 000	20	0 134	4686	1500	0	6186	1752	3 53
Small hydel	kW	30 000	30	0 124	3724	600	0	4324	2628	1 65
Coal Thermal	kW	25 000	25	0 127	3187	250	—	—	4818	
Coal cost with transport cost @Rs 0 26 /t-km[a] and marginal pit-head cost of Rs 335/t [a]										
	500	465	—	—	—	—	2240	5678	—	1.18
	800	543	—	—	—	—	2616	6054	—	1 26
	1000	595	—	—	—	—	2867	6304	—	1 31
Decentralized power generation										
Photovoltaics[b]	kWp	110 000	25	0 127	14 025	4220	0	18 245	1560	11.70
Gasifier[c]	dkW	9500	15	0 147	1395	950	4414	6760	5256	1.29
agro-waste based										
wood-based	kW	7500	15	0 147	1101	750	5992	7843	5256	1 49
Biogas dual fuel[d]	kW	9500	20	0 134	1272	950		2222	5256	0 42
Contribution of distribution line for different distances from the 33 kV grid[e]	km									
	1	43 000	25	0 127	5482	2150	—	—	—	—
	5	215 000	25	0 127	27412	10750	-	—	—	—
	10	430 000	25	0.127	54 825	21500	-	—	—	—
	15	645 000	25	0 127	82 237	32250	-	—	—	—
Irrigation/shaft power	—	—	—	—	—	—	—	—	—	—
Windmill[f]										
shallow well unit	—	25 000	20	0 134	3347	—	—	—	—	—
deep well unit	—	45 000	20	0 134	6025	—	—	—	—	—
Gasifier[c]										
agro-waste based	—	14 085	15	0.147	2068	1408	2208	5684	2628	2 16
wood based	—	12 085	15	0 147	1774	1208	2996	5978	2628	2.27
Photovoltaic[b]	kWp	240 000	25	0.127	30 600	1000	—	31 600	—	—
irrigation	—		(demand restricted to 120 d/y)						624	50 64
water supply	—		(constant demand throughout the year)						1560	20 26
Gasifier[c]										
agro-waste based	—	15000	10	0 177	2655	1500	—	4155	3504	1 19
wood based	—	1300	10	0.177	2301	1950	—	4251	2628	1 62

[a] See TERI (16), [b] Kishore & Sinha (6), [c] Sinha and Kandpal (14), [d] Sinha & Kandpal (14), [e] Includes lead-acid battery storage costs of Rs 2/kWh for wind and solar stand-alone systems Assumed annual mean daily solar insolation 5 2 kWh/m^2 See Sinha and Kishore (15) Discount rate of 12% used, [f] Sinha & Kandpal 1991, Windmill irrigation in India *Energy* 16(5), 867–874

Source National Resource Forum, *Renewable energy programmes in India*, C S Sinha, November, 1992

Policy package for renewable energy is given in Box 2.1.The biogas programme had traditionally been the single largest renewable energy programme, accounting for over half of the funds allocated. All other individual programmes have received less than 10% of the funds. In terms of numbers, however, the programme on dissemination of improved cook-stoves has been the largest followed by the biogas programme. Biogas plants and improved cook-stoves have received good acceptability among rural households. However, there is scope for considerable improvement in the implementation of these programmes.

A package of fiscal incentives and tax holidays has been introduced to enlarge private participation in renewables. The package includes

- 100% depreciation allowance
- Soft loans
- Reduced customs duties on imported materials and equipment
- Exemption from excise duty and sales tax
- Remunerative price for power fed into the grid, and
- Facilities for wheeling and banking of power

Box 2.1. Policy package for renewable energy

Among other technologies, windfarms have emerged as a viable option in the power sector. With the experience gained in the programme, and the growing interest of the private sector in this technology, wind energy can be expected to develop even more in the coming years. Small hydro plants have evolved as another promising option for electricity generation, especially in remote hilly areas where the cost of grid electricity is formidable. Among solar thermal technologies, solar water heaters (for industrial use), and solar cookers are gaining popularity. However, in both these technologies, attention needs to be paid to product development and making them more compatible with user requirements.

Though not all RETs are economically viable, environmental and social concerns (which are of equal importance in view of the need for sustainable development) make a case for their promotion in a country like India. Thus, in order to promote RETs in a systematic manner, DNES was converted to a full-fledged Ministry MNES in late 1992. And, in tune with the new policy of economic liberalization, MNES has adopted a comprehensive strategy and action plan for promoting RETs in India. The action plan shifted the focus of the programmes from state-supported development and demonstration activities to market-oriented commercialization of technologies. The thrust of the strategy now is to provide a conducive policy environment and support mechanisms that would lead to increased participation of the private sector in the utilization of renewable energy technologies.

A separate financial institution, the Indian Renewable Energy Development Agency (IREDA), set up in 1987 by the Ministry plays a key-role in implementing this package by offering loans on soft terms to users and manufacturers of different RETs (Table 2.20).

A few of the state governments and electricity boards have also adopted guidelines and policies aimed at promoting renewable energy projects in the respective states.

The manifestations of these efforts are already becoming visible. Windpower projects aggregating 1500 MW have been either installed or are under development. The National Wind Resource Assessment Programme of MNES has identified 77 locations in 9 states with a generating potential of 4000 MW of grid quality power. India will very soon rank second in the world, after the US, in wind generation.

Almost 1000 MW of small hydro power projects have either been commissioned or are under construction. As many as 2000 sites have been identified for generating over 5000 MW of power.

Biomass-based power generation is being promoted vigorously. Special programmes have been launched for using cogeneration and combustion technologies. Over 400 sugar mills operating in various parts of the country have the potential to produce around 3500 MW of power using the bagasse-based cogeneration process.

Solar photovoltaics is another exciting technology which has vast scope for application in India. With about 100 000 villages still to be electrified and over 70 million households needing electricity connections, India is implementing one of the largest photovoltaic programmes. Among the highlights of the programme are, the supply of one million solar lanterns and 50 000 solar pumps and, provision of solar-powered telephone systems to about 100 000 villages. With over 25 companies actively engaged in manufacture of photovoltaics, India has the capability to produce everything from high purity silicon to complete photovoltaic systems.

Programmes have also been initiated to use renewable energy technologies for meeting the needs of important sectors such as telecommunications, railways, and urban development.

With all these developments, the Indian renewable energy programme has attracted considerable international attention. Several bilateral and multilateral cooperative programmes are underway. Financial assistance to the tune of US $200 million has been mobilized from the World Bank, UNDP, and other sources in order to speed up the process of commercialization.

Thus, in the last two years, there has been a lot of activity in the renewable energy sector. However, the real impact of RETs on the overall energy scenario is likely to become apparent only after a few years.

Table 2.20. Lending norms of IREDA

			Lending norms of IREDA		Repayment period	
Sector	Interest rate (inclusive of interest tax)	Minimum* promoters contribution	Term loan	Ceiling on** term loan	Moratorium period (Maximum)	Total repayment period (Maximum)
Wind farms	14.50% Rebate 0.5% for timely repayments	25%	Up to 75% of total cost of eligible items under World Bank Loan, whichever is lower	—	1 year	6 years
Small hydro	14.50% Rebate 0.5% for timely repayments	25%	do	—	3 years	10 years
Biogas generation	15.50% Rebate 0.5% for timely repayments	25%	60% of total loan amount	Rs 15 million	2 years	8 years
Biomass utilization	10.30% Rebate 0.5% for timely repayments	25%	Full loan amount	—	2 years	10 years
Solar energy						
Solar thermal system						
Manufacturers	15.50% Rebate 0.5% for timely repayments	25%	Full loan amount	—	2 years	8 years
Users (direct)	10.30% Rebate 0.5% for timely repayments	30%	Full loan amount	—	2 years	8 years
Intermediaries***	-do-	30%	Full loan amount	—	1 year	8 years
Intermediaries@@	2.5	30%	Full loan amount	—	1 year	8 year
Solar P V						
Manufacturers	15.50% Rebate 0.5% for timely repayments	25%	On project to project basis	Rs 15 million	2 years	8 years
Users	10.30% Rebate 0.5% for timely repayments	25%	—	—	i) 2 years (SPV power plants) ii) 1 year others	8 years
Intermediaries***	-do-	25%	—	—		
Intermediaries@@ (domestic systems)	2.5	25%	—	—	-do-	-do-
Cogeneration for power generation	14.5	25%	40% of project cost	Rs 3 crores	3	10

Sector	Interest rate (inclusive of interest tax)	Minimum* promoters contribution	Lending norms of IREDA		Repayment period	
			Term loan	Ceiling on** term loan	Moratorium period (Maximum)	Total repayment period (Maximum)
Manufacturing of high efficiency wood burning stoves	15.50% Rebate 0.5% for timely repayments	25%	Full loan Amount	—	2 years	7 years
Purchase of biomass gasifier for power generation	12.90% Rebate 0.5% for timely repayments	25%	Full loan Amount	—	2 years	6 years for new units. 5 years to existing units
Manufacturing of Briquetting equipments Biomass gasifier Energy conservation/ systems/ equipments/devices using/operating through renewable sources Battery-powered vehicles	15.50% Rebate 0.5% for timely repayments	25%	Full loan Amount	—	2 years	8 years
Installation of high efficiency energy savings/conservation devices/systems through renewable systems/fuels	15.50% Rebate 0.5% for timely repayments	25%	Full loan Amount	—	2 years	5 years for new units. 4 years for existing units
Purchase of battery-powered vehicles based on alternate fuels such as ethyl alcohol (ethanol), hydrogen, etc	10.30% Rebate 0.5% for timely repayments	25%	Full loan Amount	—	6 months from the date of delivery of vehicle	5 years

Notes.

* The minimum promoter's contribution would be 20% of the project cost for SC/ST entrepreneurs

** The ceiling on term loan is subject to further limitations prescribed in the Operational Policy Statement approved by IREDA's Board of Directors as amended from time to time.

*** Are eligible for a spread on interest rate of lending up to a maximum of 4%.

@@ Interest @ 2.5% would be applicable from the date of furnishing of certificate of installation of domestic systems.

@ There is a rebate of 0.5% on interest for timely repayment, except for the Intermediaries.

CHAPTER 3

Trends in energy consumption

A macro picture

The growth in consumption of energy is a function of the growth in the economy, and changes in the lifestyle of households, as a result of changes in the income levels enjoyed by them. It is important to emphasize here the distinction between *energy demand* and *energy consumption*, as the two have often been used synonymously, while planning exercises in the past. Energy consumption in India reflects energy demand to the extent that it is constrained by supply shortages.

Biomass energy is still estimated to contribute towards nearly 40% of the total energy consumed in the country. Firewood is the most preferred form of biomass energy, followed by dung-cakes and agricultural residues.

The indigenous production of commercial energy in India increased from 53 Mtoe in 1972/73 to about 165 Mtoe in 1991/92, registering an average growth rate of about 6.2% per annum (Table 3.1). While coal accounted for as much as 62% of the total energy available in 1972/73, its share declined to 58% in 1991/92. In direct contrast to this, the share of oil increased. Owing to persistent shortages of coal and power supplies in the recent past, the consumption of petroleum products increased substantially. This switch

Table 3.1. Availability of primary sources of energy (Mtoe)

	1972/73	*1975/76*	*1980/81*	*1985/86*	*1991/92*
Coal					
Production	41.60	53.70	55.90	75.60	112.40
Net imports	0 25	0.23	0.68	0.89	2.90
Crude oil					
Production	7.30	8.40	10.50	30.20	30.30
Net imports	12.10	13.60	16 20	14.60	24.00
Natural gas					
Production	1.30	2.00	2.00	6.90	16.00
Net imports	—	—	—	—	—
Hydro power					
Production	2.30	2.80	3.90	4.30	6.10
Net imports	—	—	—	—	—
Nuclear power					
Production	0 09	0.22	0.25	0 42	0.50
Net imports	—	—	—	—	—
Total					
Production	52.70	67.30	72.60	117 50	165.30
Net imports	15.10	15.40	24.40	17 40	33.60

Source. Compiled from energy balances in TERI Energy Data Directory and Yearbook (TEDDY) 1990 and TEDDY 1990/91 and TEDDY 1994/95 was effected not due to the large supply of petroleum products domestically, but due to the relative ease in importing them.

Industry (including power) is the largest consumer of coal. The consumption of oil, electricity and natural gas is significant but well below the level of coal. The transport sector, over the period 1980/81–1991/92, shifted to a near total dependence on petroleum products. The residential sector's consumption of petroleum products has also increased significantly. Agriculture has emerged as the second largest consumer of electricity following industry.

Industry

The industrial sector accounts for 60% of the final energy consumption, both for energy and non-energy purposes (net of power generation). Nearly 74% of this is in the form of coal, 15% as petroleum products, and the balance as electricity. Over 42% of energy sales from the utility sector in 1991/92 were to the industrial sector. In addition, industry generates nearly 10% of total utility generation through captive power plants, most of which is consumed virtually. Natural gas consumption is as yet very small.

The industrial subsectors of iron and steel, paper, cement, fertilizers, aluminium, textiles, chemicals and petrochemicals account for nearly 80% of the industrial energy consumption.

Iron and steel sector

The Indian steel industry has emerged from a negative average growth of 0.6% during the Sixth Plan period, to a positive average growth of 6.6% per year during the Seventh Plan period. However, the performance of the steel industry in general has not been up to expectations due to the constraints on raw material input, outdated technology, and power availability.

While seven integrated steel plants are under operation in India at present, the government's focus is on sponge iron plants; both coal-based as well as gas-based. About 78% of the steel is manufactured in the integrated steel plants, while the rest is manufactured by mini-steel plants through the electric arc furnace (EAF) route. There are about 200 such plants, all of them under the private sector.

The steel industry is one of the largest consumers of energy, both in industrialized and developing countries. The steel industry accounts for up to 13% or more, of the total energy consumption in the country and about 23% of the total industrial energy consumption. The energy consumption norm lies in the range of 6–10 gigacalories (Gcal) or 0.6–1.0 tonnes of oil equivalent (toe) for every tonne of crude steel.

The sources of energy used at a steel plant can be classified into primary sources, that are purchased from outside the plant, and secondary sources, that are generated in various parts of the steel plant and can be recovered for reuse. One of the objectives of energy-efficiency improvement is to expand the use of these secondary sources as much as possible and thereby reduce the requirements for purchased energy. The main primary sources of energy for steel-making are metallurgical or coking coal, fuel oil, electricity, and natural gas. The shares of the primary purchased energy sources in total primary energy consumption are summarized in Table 3.2.

Table 3.2. Energy consumption by the steel-making process and type of purchased energy (% of calorific value)

	Steel-making process			
Energy sources	*BF-BOF*[a]	*BF-OHF*[b]	*DR-EAF*[c]	*Scrap-EAF*[d]
Metallurgical coal	71	62	—	—
Natural gas	—	—	53	—
Electricity	16	14	32	59
Fuel oil and others	13	24	15	41
Total	100	100	100	100

[a] blast furnace-basic oxygen furnace [b] blast furnace-open hearth furnace [c] direct reduction-electric arc furnace [d] scrap-electric arc furnace

The main secondary sources of energy in an integrated BF-BOF steel plant are:

- coke oven gas (COG) from carbonization of coal,
- blast furnace gas (BFG) from the reduction of iron ore with coke, and
- basic oxygen furnace gas from the decarburization of molten iron.

BFG accounts (by calorific value) for about 50% of the energy content of by-product gases, COG for 42%, and basic oxygen furnace gas for 8 per cent. In mini-mills, top-gas from direct reduction and electric arc furnaces can also be recycled. The by-product gases can be used to fuel various furnaces, or to generate steam and electric power. In some plants, these gases are flared off when excess amounts are produced as a result of the high rates in the BF, or recycling facilities are inadequate or ineffective.

The Steel Authority of India Limited (SAIL) undertook a drive to reduce its specific energy consumption during the mid-80s, and the achievements over the last five years are commendable as can be seen from Table 3.3. It is seen that for SAIL plants, the specific energy consumption has decreased by as much as 15%.

Paper

There are 327 paper mills in the country, 33 large integrated paper mills (IPM), 260 small and the rest medium-sized, with a total installed capacity of 3.28 Mt. The operational capacity stands at 2.52 Mt and the capacity utilization is 60%. India

Table 3.3. Reduction in specific energy consumption

Plant	1986/87 (Gcal/tcs*)	1990/91 (Gcal/tcs)	% Change
BSP	10.51	8.63	(−) 17.7
DSP	12.03	11.26	(−) 6.3
RSP	11.65	10.05	(−) 13.6
BSL	10.61	9.10	(−) 14.2
IISCO	17.17	16.03	(+) 6.6
SAIL	11.27	9.53	(−) 15.4

*tonnes of crude steel

has established a substantial capacity for the manufacture of paper, based on non-wood/agro-waste fibre pulping, and such capacities account for almost 50% of the national production. About 70% of the total 260 small mills are based on soda chemical pulping of agricultural residues and do not have any facility for chemical recovery. Rayon-grade pulp is made exclusively in five mills.

Presently, for the production of 20 Mt of paper, more than 500 000 tonnes of fibrous raw materials are being imported. About 1.44 Mt (43.7%) of the installed capacity is reliant on forest-based raw materials.

Table 3.4 shows the general trend in the percentage consumption of different raw materials by the pulp and paper industry. Bamboo is still predominant as a raw material but there has been a massive jump in the percentage consumption of hardwood over the years.

Table 3.4. Raw material consumption in paper industry (%)

Raw material	1958/59	1975/76	1990/91
Bamboo	70	51	38
Hardwood	4	28	34
Softwood	6	3	2
Agricultural residues and gases	16	12	18
Waste paper	4	6	8

Source. Appropriate industrial technology for paper products and small pulp mills; #3 UNIDO Monographs on Appropriate Technology, pp 55 1979

For the paper industry, energy is an important input and accounts for about 15–20% of the total manufacturing costs. This industry has an annual energy bill of over Rs. 200 crores which is approximately 2.5% of the total individual sector energy bill.

However, 80–85% of the energy is low-grade energy (200 °C) in the form of process steam, and the rest is high-grade energy in the form of electric power. The paper industry as a whole, consumes around 4.0 Mt of coal. The overall specific energy consumption varies from 7.26–13.25 million kilo calories (Mkcal) per tonne, 10–14 tonnes of steam per tonne and 1200–1600 kWh of power per tonne.

Coal is commonly used for generating steam required in all small paper mills. About 3.4 tonnes of coal is required per tonne of paper made in agricultural residue-based mills, and the corresponding coal requirement in waste paper based mills is 1.5 tonnes per tonne of paper. In all these boilers, coal lumps of 2.5–5.0 cm diameter are used. Indian coals contain 0.5–0.8% sulphur.

The energy conservation potential in the Indian paper and pulp industry is 20–25%. Integrated Paper Mills (IPMs) generally have captive cogeneration systems which use back pressure or extraction-cum-condensing turbines to generate power. This captive generation varies from 25–60% of the mill's total power requirement.

Cement

The Indian cement industry, the 5th largest producer in the world, is a mixture of medium and large capacity cement plants, ranging in unit capacity per kiln from as low as 10 tonnes per day (tpd) to as high as 4000 tpd. Most of the production of cement in the country (94%) is by large cement plants, which are defined as having a capacity of more than 600 tpd. There are, at present, 51 cement companies in the country with a total of 97 large rotary kiln plants. Of these, 76 plants operating under the private sector are faring particularly well with an average capacity utilization of 89%, as against the industry's overall weighted average capacity utilization of 82%.

The production of different varieties of cement by the industry in the year 1992–93 is shown in Table 3.5.

Table 3.5. Product mix for cement

	Production	
Type of cement	*Absolute (Mt)*	*Per cent share*
Ordinary portland cement (OPC)	36.46	71.9
Portland pozzolana cement (PPC)	8.34	16.4
Portland slag cement (PSC)	5.37	10.6
Others	0.55	1.1

The per capita consumption of cement in India is only 53 kg, much less than the world average of 200 kg. The Government remains the single largest consumer of cement in India, absorbing almost 40% of the total cement produced.

The share of contribution from wet process cement plants to the total installed capacity is slowly decreasing over the past three decades, mainly due to establishment of new dry process units and conversion of some of the wet process plants. A glimpse of the changing process profile of the Indian cement industry is provided in Table 3.6.

Table 3.6. Process share in installed cement capacity

Process	*Installed capacity (%)* *1960*	*1970*	*1980*	*1993*
Wet	94.4	69.5	61.6	16
Semi-dry	4.5	9.0	5.7	2
Dry	1.1	21.5	32.7	82

The cement industry is energy-intensive and its main energy requirements are thermal and electrical energy. Thermal energy is generally obtained from coal or fuel oil and electrical energy is obtained either from the grid or the captive power plants of individual manufacturing units. At the current level of cement production, the coal consumption by the industry alone stands close to 11 Mt and the annual power requirement is around 7 TWh. The total energy bill of the sector amounts to approximately Rs 2000 crore per annum.

There exists a wide variation in the energy consumption pattern of different cement plants depending upon various factors. Energy consumption norms have been developed by taking some of these factors into account. Table 3.7 presents section-wise energy consumption norms for the industry.

Table 3.7. Energy consumption norms

Plant section	*Normative value* *Dry process plants*		*Wet process plants*	
Crushing (kWh/t of lime stone)	1.0–3.0		1.0–3.0	
Raw material grinding				
Ball mill	22–28 kWh/t[a] of RM[b]		16–22 kWh/t of slurry	
Roller mill	15–18 kWh/t of RM		—	
Kiln section	*< 1500 tpd*	*≥ 1500 tpd with precalculation*	*< 600 tpd*	*≥600 tpd*
Electrical energy (kWh/t)	30–35	30–35	12–18	12–18
Thermal energy (kcal/kg)	850–1000	800–900	1400–1550	1350–1550
Coal mill section (kWh/t of coal)				
Ball mill	25–35		25–35	
Roller mill	20–25		20–25	
Tandem mill	25–35		25–35	
Cement grinding (kWh/t of cement)				
OPC	30–40		30–40	
PPC	35–45		35–45	
PSC	55–60		55–60	

[a]kilowatt hours per tonne [b]raw meal

Thermal energy source constitutes 65–78% of the total energy requirement of a plant while the balance is the electrical component. However, in terms of value of the share of electrical and thermal energy, they are equally placed at roughly 50%. The share varies by types of processes employed.

Fertilizer industry

Of the total energy consumption by the fertilizer industry, the share of phosphatic fertilizers constitutes less than 1 per cent. India does not produce any potassic fertilizers.

Uncertainty of availability, coupled with high prices of the imported nitrogenous fertilizers, and rapidly increasing demand during the early seventies had given a momentum to the building up of indigenous production capacity in India. This was further accelerated in the eighties by the addition of new gas-based plants spurred on by the newly found reserves of natural gas at Bombay High. The growth of installed capacity and production of nitrogenous fertilizers is given in Table 3.8.

The sector-wise break-up of capacity and production of nitrogenous fertilizers is given in Table 3.9. Plants under the private and cooperative sectors, which are relatively new and are either gas-based or naphtha-based with a high overall performance, have capacity utilization levels of more than 100%. However, the public sector units, including some sick units which are coal based, are operating at lower capacity utilization levels.

Table 3.8. Production/capacity growth of nitrogenous fertilizers

Year	*Capacity (Mt)*	*Production (Mt)*	*Capacity utilization (%)*	*Imports (Mt)*	*Consumption (Mt)*
1960/61	0.2	0.1	69.1	0.4	0.2
1970/71	1.3	0.8	62.0	0.5	1.5
1980/81	4.6	2.2	52.8	1.5	3.7
1985/86	6.7	4.3	75.5	1.6	5.7
1990/91	8.1	7.0	85.8	0.4	8.0
1991/92	8.3	7.3	88.6	0.6	8.0
1992/93	8.5	7.4	88.1	1.2	8.4

Sources

1/ Pitam Singh and U S Awasti—Fertilizer Industry in India (Part-1), 1992

2/ Fertilizer Statistics (1992/93)

Table 3.9. Sector-wise break-up of capacity and production

Sector	*Capacity (Mt) (on 1.10.1993)*	*Production (Mt) (1992/93)*	*Capacity utilization (%)*
Public	4.4 (51%)	3.0 (41%)	69.4
Private	2.6 (31%)	2.7 (36%)	103.0
Co-operative	1.5 (18%)	1.7 (23%)	111.3
Total	8.5 (100%)	7.4 (100%)	88.1

Source. Fertilizer Statistics (1992/93)

The main raw material for production of all the nitrogenous fertilizers is ammonia. Urea accounts for 85% of the total installed capacity of nitrogenous fertilizers and about 90% of ammonia produced in the Indian industry is used for urea production. The remaining 10% is consumed by other straight and mixed fertilizers which are lesser energy intensive than urea. Ammonia production is the most energy intensive stage of all nitrogenous fertilizers, accounting for 80–90% of the total energy consumed by the finished fertilizer.

The consumption of coal as feedstock/fuel in the fertilizer industry will decline further, owing to the feedstock change of the two coal-based plants. Consumption of naphtha, natural gas, and fuel oil by the nitrogenous fertilizer industry is given in Table 3.10.

Table 3.10. Feedstock consumption in ammonia production

Year	*Naphtha (Mt)*	*Natural gas (Mcu m)*	*LSHS[a]+FO[b]+HHS[c] (Mt)*
1980/81	1.2	611	1.1
1984/85	2.4	1603	1.5
1985/86	2.4	2500	1.5
1986/87	2.4	3335	2.0
1987/88	2.1	3490	1.9
1988/89	2.4	5334	2.1
1989/90	2.3	6578	2.1
1990/91	2.4	6556	2.2
1991/92	2.4	5509	2.5

[a]low sulphur heavy stock [b]furnace oil [c]hot heavy stock
Source. Fertilizer Statistics (1992/93)

Due to the large reserves of natural gas identified in Bombay High, natural gas utilization in ammonia production has increased over the years. The share of different feedstocks in the production of ammonia during 1992/93 is given in Figure 3.1.

The changes in the type of feedstock, technology etc., which the Indian ammonia industry witnessed, resulted in substantial improvement in the overall energy-use efficiency. The energy consumption per tonne of ammonia for different feedstocks is given in Table 3.11. It is observed from the table that during the five year span of 1987–1992, the average specific energy consumption for gas-based plants has improved by 7.2% and for naphtha-based plants by 8.2%.

Table 3.11. Specific energy consumption (Gcal/tonne) of ammonia

Feedstock	1987/88	1988/89	1989/90	1990/91	1991/92	1992/93
Gas	10.2	10.0	9.6	9.6	9.6	9.5
Naphtha	12.8	12.2	12.4	11.9	11.7	11.7
Fuel oil	13.9	14.3	14.4	15.1	13.5	13.9
Coal	33.5	33.8	38.9	39.1	39.7	42.7

Source Fertilizer Statistics (1992/93)

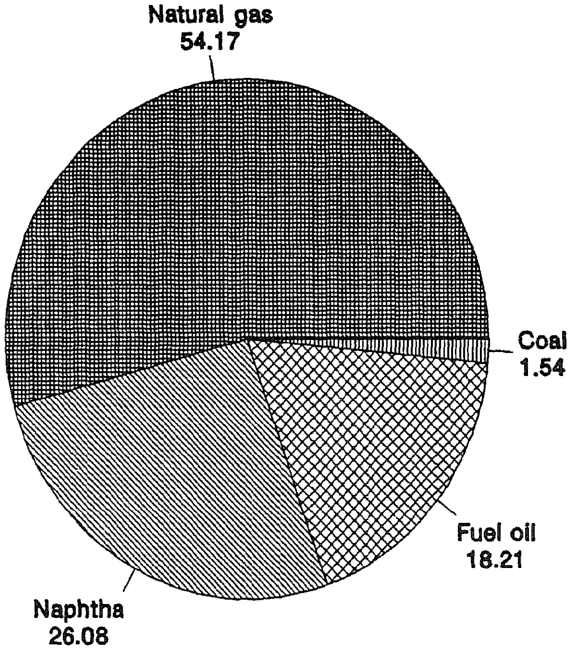

Figure 3.1. Share of feedstocks in ammonia production (%) 1992/93

Aluminium industry

The aluminium industry in India, which began in the thirties, has made considerable progress during the last five decades. The installed capacity has increased from 4000 t in 1950 to 625 000 t in 1992/93. At present, five companies (two in the public sector and three in the private sector) are producing aluminium. Details regarding capacity, production and capacity utilization for the year 1992/93 are provided in Table 3.12.

The per capita consumption of aluminium in India is 0.5 kg as against 25 kg in developed countries like the USA, Japan, etc. The electricity transmission lines account for about 40% of the total domestic aluminium consumption followed by consumer durables/household equipment manufacturers (25%), transport (17%), packaging and canning industry (18%) and others (11%).

Bauxite is the raw material used for the production of aluminium in India. India possesses nearly 8 per cent of the world's known reserves of bauxite amounting to about 2650 Mt.

The energy cost for both thermal and electrical energy, represents nearly 60% of the total cost of aluminium production. Energy inputs are electricity, coal, fuel oil, calcined petroleum coke, pitch and tar. Electricity is the major energy input in aluminium

Table 3.12. Details of Indian Aluminium Companies as in 1992/93

Company	Capacity ('000 t)	Production ('000 t)	Capacity utilization (%)
INDAL[a]	117	38	32
BALCO[b]	100	94	94
NALCO[c]	218	191	88
HINDALCO[d]	165	163	100
MALCO[e]	25	—	—
Total	625	486	78

[a]Indian Aluminium Limited [b]Bharat Aluminium Company [c]National Aluminium Company [d]Hindustan Aluminium Company [e]Madras Aluminium Company

Note. MALCO suspended production in April 1991 because the company is no longer viable technically or financially. Its cost of production was Rs 45 000/t against the market price of Rs 35 000/t, rendering the unit inviable. The company has submitted two revival proposals and also envisaged the export of aluminium as a part of the resuscitation strategy

Source. Market and Market Shares CMIE Pvt. Ltd., February, 1994

production. It has a share of 40% in the total cost of production. At present in India, average consumption of electricity is roughly 15 500 kWh/t of aluminium.

Process-wise consumption of different types of fuel for three of the aluminium manufacturing companies for the year 1989/90 is shown in Table 3.13.

Table 3.13. Process-wise consumption of energy per tonne of product for three aluminium plants

Energy Type	NALCO		HINDALCO		INDAL	
AC power (Smelter)	14 910	kWh	17 200	kWh	17 390	kWh
Power (Alumina)	351	kWh	—	—	257	kWh
Furnace oil (Smelter)	89	litre	246	litre	54	litre
Furnace oil (Alumina)	84	litre	2307	litre	231	litre
Coal for steam	628	Kg	—	—	1240	Kg

Note. HINDALCO has consolidated figures for smelter and refinery

Source. Minerals & Metals Review, Annual 1990

Cotton textile industry

The textile industry continues to be the largest industry in the country. It accounts for about 20% of the total industrial output, and contributes to nearly 30% of the total value of exports. The Indian textile industry continues to be predominantly cotton based with cotton accounting for 70% of the fabric production in the country. This industry consumes about 4 Mt of coal, 500 000 tonnes of fuel oil and 8500 million units of electricity accounting for about 9 per cent of the commercial energy consumed in India. Fuel and power account for about 12–15% of the total cost of production.

There are 686 textile mills operating in India with major textile complexes. In 1990, the overall installed capacity was 20 million bales of cotton per year. The production in the Indian powerloom industry was of the order of 400 million metres of cloth per year. The powerloom and handloom sectors have increased their respective shares marginally to 71.3% and 21.1% at the expense of the mill sector whose share has declined to 7.6%.

The primary inputs in textile manufacture are steam and power. The textile industry accounts for 6.5% of industrial electricity consumption (utilities and non-utilities). While power consumption in the process department amounts to 20–25% of the total energy, steam consumption is of the order of 80–85%. About 80–90% of power consumption in a textile mill goes for motive power while the rest is used for illumination, heating, etc.

Caustic soda industry

Chlorine and caustic soda are produced concurrently by electrolysis of brine. Nearly 82% of the caustic soda produced in the country is by the mercury cell process, 11.4% from the membrane cell, 6.5% from the diaphragm cell, and 0.1% from the chemical process.

A majority of the caustic soda producing units use coal as the source of thermal energy. For over a decade now, the industry has shown interest in energy conservation measures, and pollution abatement methods and therefore, in the membrane cell technology due to economic, technological and environmental advantages. There has been a concerted effort throughout the country to reduce the energy consumption in caustic soda producing process plants. The process-wise production and specific energy consumption figures are given in Table 3.14 and Table 3.15.

Table 3.14. Process-wise caustic soda production data

	Production (Mt)			
Year	*Membrane process*	*Mercury process*	*Diaphragm process*	*Total*
1987/88	12 918	708 040	56 976	777 934
1988/89	31 210	782 200	63 000	876 410
1989/90	103 973	778 559	70 279	952 811
1990/91	115 774	834 990	66 184	1 016 948
1991/92	155 406	845 939	52 127	1 053 472

Soda ash industry

The Indian soda ash industry has developed to such an extent that the country is not only self-sufficient in this vital basic chemical but also has a surplus capacity.

There are, presently, six soda ash manufacturing units in India, four based on the Solvay process and two on the Modified Solvay process or Dual process. In the Dual process, calcination of limestone is not required thereby resulting in substantial energy savings. There is also a substantial reduction in steam as the steam distillation recovery for ammonia is also eliminated. The Modified Solvay process is economical if the co-product, ammonium chloride, can be successfully used as fertilizer.

Table 3.15. Total production and process-wise specific energy consumption in 1990/91

Process	Production in 1990/91 (tpa)	Specific energy consumption (kWh/t)		
		Thermal[1]	Electrical	Total
Membrane cell	115 774	785	2450	3235
Mercury cell	834 990	370	3050	3420
Diaphragm cell	66 184	1100	2800	3900

Source. Department of Scientific and Industrial Research (DSIR) report on Technology Evaluation in Caustic Soda Industry, 1992

The two major energy consuming areas, accounting for 70% of the total energy requirement, in the Solvay process are:

- calcination section for the conversion of bicarbonate to soda ash, and
- the ammonia distillation section for the recovery of ammonia from ammonium chloride.

At the end of the First Five Year Plan (1951–1956), the capacity for soda ash production was a mere 90 000 tonnes which increased to 1.5 million (15.5 lakh) tonnes at the end of the Seventh Five Year Plan.

The anticipated capacity utilization of the soda ash industry during the period 1993–97 is 90.9%. The weighted average specific energy consumption could not be calculated because of the non-availability of data on process-wise production and energy consumption. One of the largest manufacturers of soda ash by Akzo dry lime process in the country is M/s. Gujarat Heavy Chemicals Ltd., located at Veraval, Gujarat. This plant produced 230 041 Mt and 378 052 Mt during 1988/89 and 1990/91, while the installed capacity was 420 000 Mt of soda ash during those periods. The specific energy consumption decreased from 3073.1–2458.7 kWh/t during that period because of the substantial increase in capacity utilization from 54.7%–90% and the in-house energy conservation measures adopted.

Petrochemicals

The production of basic petrochemicals in India started during the 1960s. While the Government encourages both private and public sector ownership in all phases of petrochemical manufacturing, the public sector is the leader in the production of olefins and synthetic resins and is expected to continue to play a prominent role. In other sub-sectors such as synthetic fibre, rubber and detergents, private sector participation is as much as 70%.

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[1] The corresponding specific thermal energy consumption in million calorie per tonne is 2070, 1000, and 2980 from the membrane, mercury, and diaphragm cell processes.

Specific thermal energy consumption of 3–3.3 tonnes of steam per tonne of caustic soda is approximately equivalent to 800 kWh/t of caustic soda

It is projected that the growth rate of industries in the petrochemical sector would be above 10%. The growth of the petrochemical industry, however, depends on many factors like crude refining capacity, quantum of naphtha available, policy and programme of the Government, availability of technical know-how, financial allocations, etc.

Petrochemicals are manufactured from petroleum feedstocks like naphtha and natural gas and molasses-based alcohol. At present, naphtha is the dominant feedstock in India. The sources of hydrocarbon raw materials for making basic petrochemicals in India are:

- petroleum refineries (naphtha, kerosene, LPG), and
- natural gas fractionation (C2, C3, C4 fraction), natural gas liquid (NGL) condensates.

The specific energy consumption of dimethyl teraphthalate (DMT) and polyvinyl chloride (PVC) of a typical plant for the year 1993/94 is given below (Table 3.16):

Table 3.16. Specific energy consumption of DMT and PVC for 1993/94

	DMT	*PVC*
Steam (t)	7 007	1.1
Electricity (kWh)	291	205
Fuel (tonnes equivalent)	0.105	—
Cooling water (m^3)	390	161
Treated water (m^3)	—	5.4
Nitrogen (Nm^3)	72	0.634

The specific energy consumption of polyester filament yarn (PFY) of a typical plant for the year 1993/94 is given below:

Steam (t)	5284
Electricity (kWh)	0.255
Cooling water + treated water (m^3)	48
Nitrogen (Nm^3)	54

Transport sector

The transport sector is a major energy consuming sector, particularly of oil. Energy consumption in the transport sector has increased at the rate of 3.1% per annum between 1970/71 and 1980/81 and 4.8% per annum between 1980/81 and 1991/92. There has also been a gradual shift from coal to oil as the main fuel in the railways resulting in the share of coal in total transport energy consumption declining from nearly 30% in 1970/71 to 6.8% in 1991/92.

The economic growth of the last few decades and the growth in international trade, would not have been possible if the growth in transport infrastructure had been less adequate. Not only has the total volume of passenger and goods traffic in the railways increased, but the average lead distance over which these are moved has also increased significantly, from 52 km to 80 km in the case of passengers and 520–720 km in the case of goods over the period 1950/51–1992/93. These increases are more pronounced in the road sector.

Rapid urbanization, especially around larger cities has brought acute problems of urban transport. The pattern of transportation in urban centres differs considerably and is determined by factors such as size of the city; the employment characteristics; industrialization; commercial growth; topography and the urban form; and structure of the city. In view of the large number of cities in India and the prevalent socioeconomic environment, road based systems will continue to play an important role in the movement of passengers and freight in cities of all sizes. Increase in income level, inadequate provision of public transport services, unconstrained expansion of cities and minimal importance to non-motorized vehicles in urban area, have given rise to a phenomenal growth in the private vehicle population (at the rate of 16% per annum during the last decade).

Railways

The Indian Railway is the second largest system in the world under a single management. It is a multi-gauge system operating on three gauge—Broad (BG), Metre (MG) and Narrow (NG). At the end of March 1994, the route length of the rail network comprised 62 500 route km. About 56% of the total route km is on the broad gauge, accounting for 90.5% of the freight tonne km and about 83% of the total passenger km.

The electrified railway network increased at an average annual rate of 8.5% from 1961–1994. Electric traction at the end of 1993/94 constituted about 18.8% of the total route km and accounted for more than 42% of the total gross tonne km of freight traffic on BG and about 35% of the total passenger kilometres. The Government of India initiated the track electrification programme in the fifties. However, given the capital intensity of electrification and the fact that it is economical only if traffic density exceeds a certain threshold level, using diesel in railways was considered a viable alternative in the interim. Furthermore, a concerted effort to phase out steam engines completely by the year 2001 also led to an increase in diesel traction.

Energy constitutes a little over 20% of the railways' working expenses. Therefore, priority is being given to energy-conserving measures, like the accelerated phasing out of energy-inefficient steam locomotives, retrofitting fuel-efficient kits on diesel locomotives, fitting choppers and thyristors on electric locomotives, and introducing light-weight coaches and wagons.

There has been a steady decline in the overall energy consumption intensity of the rail transport system since 1970/71, but only due to a major switch in locomotive power, from energy-intensive coal to diesel and electricity (intensity of steam locomotion in fact, increased as steam engines began to be used increasingly for short haul movements, with several halts).

Road transport

The growth of motor vehicles in India has been faster than the population growth in the country. The number of vehicles per 1000 population went up steadily from 3 in 1971/72 to about 25 in 1990/91—an increase of nearly eight times. The growth of motor vehicles in India between 1971/72 and 1991/92 is given in Figure 3.2. The noticeable feature about the growth in motor vehicles is the explosion in the number of two-wheelers.

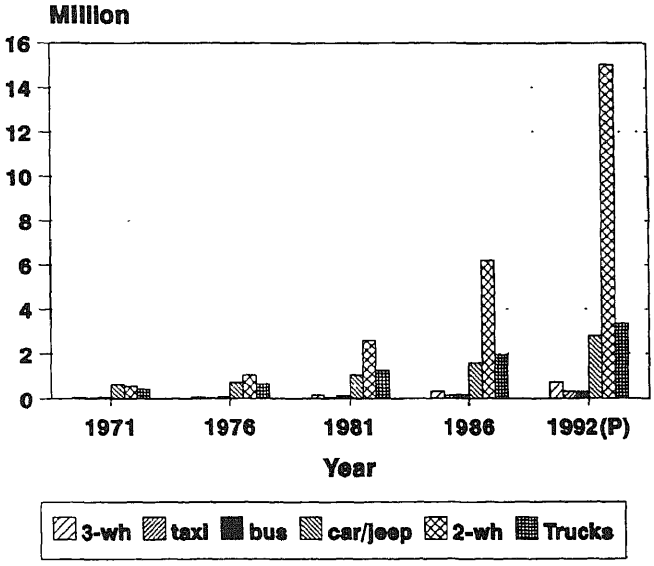

Figure 3.2. Growth of motor vehicles

Against the nearly tenfold increase in the number of motorised vehicles, the total road network in the country merely doubled from 1.01 million km in 1971/72 to 2.04 million km at the end of 1990/91. National highways constitute hardly 1.7% of the total road network but carry nearly 40% of the total traffic. The total length of national highways has increased only by about 20% in this period. The share of road traffic in passenger movement was about 77.5% and about 55% in freight movement in 1988/89.

Road-based passenger services are provided both by the public and the private sector in the country. While the total number of passenger buses is estimated to have increased from 0.15 million in March 1981 to 0.31 million in March 1990 (.35 million in March 1993), the share of the public sector buses in the country as a whole has declined from 45% to around 33%. In most major urban centres, private modes will continue to form the predominant means of transport in the forseable future with consequent problems of congestion, higher energy consumption and heavy atmospheric pollution.

Water transport

Both inland water transport (IWT) and coastal shipping have played a limited role in India. Indian water transport can take place only where rivers exist. However, the rivers may not be deep and/or wide enough to allow the use of mechanized watercraft. Besides, some rivers may be used by mechanized craft only during and after the rainy season. The importance of IWT has declined, due to the extension of road network and with the construction of bridges to facilitate river crossings by rail and road.

Coastal shipping also operates under various constraints. Although like IWT, it entails no investment in line haul facilities, loading and unloading operations at ports have generally been slow. Some ports however, have improved considerably in recent years. The Indian merchant fleet capacity has also increased rather steadily, and it now carries about 37% of India's overall cargo traffic for international trade.

Air transport

Air traffic in India has grown very rapidly since the early seventies. The three major carriers are Air India (international), Indian Airlines (domestic) and Vayudoot (domestic). Indian Airlines also operates on certain medium distance international routes to some Asian countries. With the economic reforms which have also liberalized private participation in air transport, several private airlines and air taxi operators are also operating in the country.

Relevant information is available only for Indian Airlines, which is the premier air carrier operating on domestic routes. The overall energy intensity of Indian Airlines has decreased. It is difficult to estimate energy intensity of Indian Airlines from published sources. However, according to an estimate made by Indian Airlines, the intensity reduced from 0.083 litres of aviation and turbine fuel (ATF) per available seat-km in 1970/71 to about 0.049 litres per available seat-km in 1982/83.

Household sector

Urban household energy demand

Urbanization is a natural consequence of economic changes that accompany a country's development. The contribution of the urban sector to India's GDP in 1950/51 was estimated at 29%, which increased to 47% in 1980/81 and is likely to rise to almost 60% by the turn of the century. However, the positive aspects of urbanization are often overshadowed by the evident deterioration in the physical environment and quality of life.

This is largely caused by the ever-increasing gap between the demand and supply of essential services and infrastructure.

The urban population of India in 1991, according to the Population Census 1991, was 217.18 million, spread over 3768 urban agglomerations/towns. The rapid pace of urbanization and the diverse urban growth patterns have important implications for energy use. Consumption of total commercial energy by households—largely urban—increased at the rate of 8.1% per annum over the period 1981–91. Liquefied petroleum gas (LPG) consumption has been growing 18% annually for the period 1984/85–1989/90. During the same period, electricity consumption grew by 13% and kerosene by 7 per cent, but demand for soft coke went down by about 8 per cent annually.

Comparatively little research has been done in India to assess the overall energy implications of different patterns of urbanization. The major household energy studies on which macro level analyses are based, are:

- the survey conducted by the National Council of Applied Economic Research (NCAER) in 1978/79 in about 7500 rural households and 5500 urban households, results of which were published in 1985, and
- the consumption expenditure survey for 1973, 1978, 1983, 1987/88 and 1989/90, conducted by the National Sample Survey Organization (NSSO).

A few micro level studies have also been done in different cities in India over different periods of time. In view of the variations in coverage, methodology and focus in the different studies, comparisons between them have become difficult. The Tata Energy Research Institute (TERI), New Delhi, also carried out household surveys during 1987/88 in ten cities spread all over the country, to understand the energy consumption pattern in households belonging to different socio-economic classes (Box 3.1).

Six types of energy sources were found to be consumed in urban households. These include, LPG, kerosene, soft coke, firewood, dung-cake and electricity. Monthly per capita consumption of households using these fuels by different income groups is given in Table 3.17.

Table 3.17. Monthly per capita energy consumption in urban households (*user+non-user households*) by income groups (1987/88)

		Income class (Rs/month)				
Fuel type	*Unit*	*<400*	*400–800*	*800–1200*	*1200–2400*	*> 2400*
LPG	kg	0.24	0.97	1.33	2.17	4.43
Kerosene	l	0.97	1.08	1.48	1.40	0.99
Soft coke	kg	0.30	1.81	1.39	0.95	0.17
Firewood	kg	10.52	8.36	7.69	3.83	1.42
Dung-cake	kg	3.67	1.50	3.10	0.55	0.06
Electricity	kWh	6.77	12.21	21.97	52.92	151.87

In the TERI survey, urban areas of the country were broadly divided into three categories by size of population: class I (large) cities, each with population of 100 000 and above; class II and III (medium) towns together, each with population between 20 000 and 99 999 and class IV, V and VI (small) towns together, each with population less than 20 000. Approximately, one thousand households in the ten cities with a regional spread were surveyed.

While data were collected on the basis of 13 different income groups, these were later aggregated into five income classes.

During the household survey, fuel consumption figures were recorded separately for various enduses (like cooking, water heating, space heating, space cooling, lighting, and others) in physical units such as kilograms or litres. The survey data was analysed to estimate the per capita consumption of different fuels across the five income categories.

BOX 3.1

The data from Table 3.17 reveals the following:

- per capita LPG consumption went up steadily with income from 0.24 kg/month in the lowest group to 2.17 kg/month in the highest group,
- use of kerosene per person increased with a rise in income up to the third income category (from 0.97–1.48 l/month), but dropped steadily in the last two income categories,
- firewood consumption fell from 10.52 kg/month per person in the lowest income group to only 1.42 kg/month in the highest income group.
- dung-cake is mainly used by the urban poor with a household income of less than Rs 1200 per month,
- per capita consumption of electricity is significantly different between the lowest and the highest income category. In fact, the consumption level increases by over 20 times with increases in income level.

The TERI study suggested that at the lower income category, LPG, although a preferred fuel, is not used because of inability of households in this category to afford its use. The second choice is probably kerosene and the third, soft coke and lastly, firewood. However, lower income households choose kerosene, soft coke and wood depending upon their availability Thus, the supply, availability and affordability factors play a key role in shaping energy consumption patterns especially in the lower income category of households.

Energy consumption by enduse

The utilization of total (gross) energy for different enduses has been estimated and presented in Figure 3.3. Energy consumption for cooking was found to be the highest (57%), followed by space cooling (18%), lighting (9 per cent), others (8 per cent), water heating (7 per cent) and the rest (1 per cent) went for space heating.

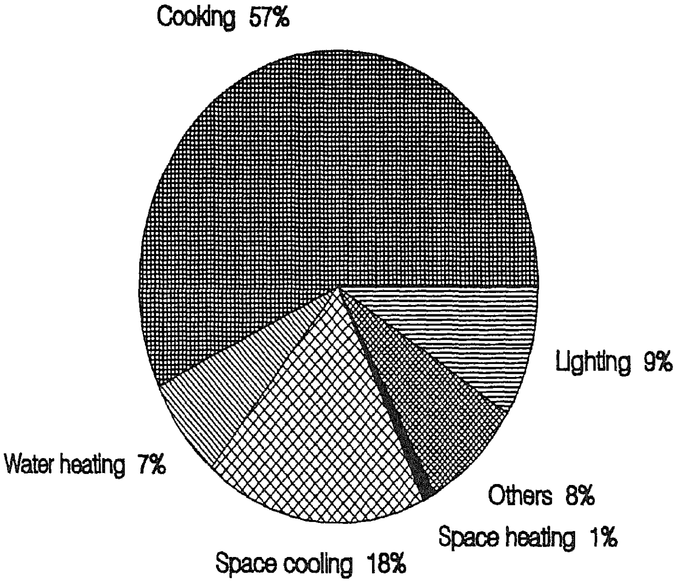

Figure 3.3. Share of energy consumption for different enduses in urban households

Total energy consumption for various enduses has been converted into *useful energy* by using average device efficiencies as they exist today.

Energy used for cooking was found to be about 5 times higher in the highest income group as compared to the lowest. Similarly, for water heating, the annual per capita useful energy demand went up steadily from 14 688 kilocalories (kcal) in the lowest income category to 80 784 kcal in the highest. The corresponding figures for space cooling (using only electrical appliances) was 26 683–809 064 kcal (nearly 34 times increase from the lowest to the highest income category). Use of energy for lighting went up from 2 331 492 lumen-hours annually in the lowest income group to 6 347 746 lumen-hours in the highest income group (about 2.5 times increase). Finally for other enduses, the energy demand in the form of electricity went up by about 4.3 times—from 38 189 kcal in the lowest to 164 995 kcal in the highest income group.

Figure 3.4 shows the annual per capita useful energy consumption for different enduses except lighting. As income rises, the share of energy for cooking declines. On the other hand, share of energy used for what could be termed as *non-essential* services such as space cooling, water heating, space heating and others, increases. The households in the lower income categories depend upon kerosene for lighting. As income rises, this proportion drops sharply, with a shift to electricity.

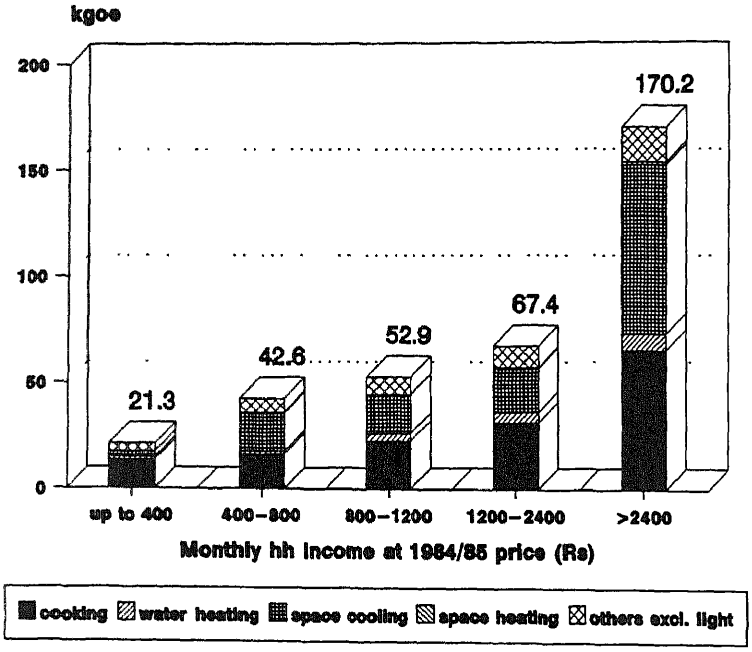

Figure 3.4. Per capita useful energy consumption

Rural household energy demand

The rural energy scenario in India is dominated by the household sector which accounts for 75% of the total energy consumed. The fuel consumption pattern of the household sector is characterized by: an overwhelming dependence on biomass fuels, especially fuelwood; dominance of cooking among the enduses accounting for over 90% of the energy consumed; collection of biofuels at *zero private cost* with very little monetization; low penetration of commercial fuels owing to high costs and supply constraints; and the modest impact of renewable energy technologies.

The predominance of household energy requirement largely fulfilled by biofuels is a well known characteristic of the rural energy system in most, if not all, developing countries. Though the qualitative aspects of rural energy consumption have been reasonably well documented and are understood fairly well, there exists a large degree of variability and an inadequate quantitative understanding of the factors affecting this variability.

Nearly all the demand estimation studies for rural areas of India have considered only the population changes insofar as volume effects are concerned. This is partly because, there is very little evidence of a correlation between energy consumption and income in the rural areas, even if it can be established that the benefits of economic growth percolate to rural areas. The lack of information on the structural changes and the likely impacts of such changes is even more acute. In the absence of an understanding of the factors influencing energy demand, estimation of energy consumption in the past has essentially used estimates of per capita energy consumption based on field surveys and trends in population growth.

Some of the major points regarding past attempts to estimate demand on the basis of energy requirement (as opposed to consumption) for the household sector are:

- all policy studies (Energy Survey of India Committee, 1965; Working Group on Energy Policy 1979; Energy Demand Steering Group 1986), except the Advisory Board on Energy (ABE) 1985, relied on energy consumption norms of the Energy Survey of India Committee 1965 of 510 kcal or 2.13 million joules (MJ) per capita daily. The Energy Survey of India (ESI), on its part, based the consumption figure on the National Council for Applied Economic Research (NCAER) surveys conducted during 1958–60,
- though all the above studies had access to survey data at the district and state level, they appear to have used only national averages, thereafter desegregating requirement at the state level. Obviously, information regarding the regional variation in requirements is lost in the process and the difference in the requirement is purely due to the difference in population, and
- the most crucial aspect, insofar as the energy policy and technology options are concerned, is the fuel mix for meeting the energy requirement. None of the studies following the ESI made any serious attempt to examine this issue. There has been no attempt to look at the variation in the mix of biofuels over time and the little effort that has been made in this direction was restricted to the role commercial fuels (kerosene and electricity) could play in changing the proportional contribution of different fuels—the biofuel mix has been assumed constant over time in all studies. In many studies, the national average of the fuel mix was used to estimate the state-wise requirements of different biofuels. As with the requirement estimates, this led to loss of information regarding the proportional contribution of different biofuels at the state level.

The most frequently used data on rural household energy consumption patterns came from the surveys of the NCAER, the last of which was conducted in 1978/79, and published in 1985. This survey covered 13 010 sample households spread over 18 states of which the rural sample was 7500 households in 600 villages selected from 300 districts.

The other notable source of rural energy consumption data is the Integrated Rural Energy Planning (IREP) exercise of the Planning Commission of the Government of India. This programme attempts to prepare and implement energy intervention plans for an administrative cluster of about 100–150 villages (termed as a Block) and involves sample surveys for determining energy consumption patterns as a part of this exercise.

Apart from this, the Department (now, Ministry) of Non-conventional Energy Sources, ABE, and various state energy development agencies have commissioned a large number of village level surveys in different regions of the country. The data thus collected through the rural energy surveys conducted during 1985–92 in India were compiled and analysed to create a rural energy database (REDB) and to identify regional variations in the energy consumption pattern (TERI Energy Data Directory and Yearbook—1990/91). Studies in the past had indicated that agro-climatic conditions are an important factor influencing the use of biofuels in rural areas. Both the level of biofuel use, and the fuel-mix is believed to be influenced by the availability of different biofuels, which in turn, depend on the agro-climatic conditions. The results based on the analysis of the data compiled for 638 villages in 17 states spread over 14 of the 15 agro-climatic regions in the country comprise the REDB. Desegregating these figures at the district level, the data were regrouped to arrive at state level consumption figures, presented in Table 3.18.

REDB confirms the predominance of fuelwood and the analysis indicated 95% confidence interval for per capita (pc) consumption (national aggregates) for cooking in the range of 1.10–1.34 kg/pc/d. The consumption of dung-cake was lower at 0.40–0.49 kg/pc/d. The agricultural residue consumption was marginally higher at 0.47–0.63 kg/pc/d. The REDB estimates suggest the following with regard to the per capita biofuel consumption across agro-climatic zones:

- variation in the fuelwood used for cooking has a high degree of statistical significance,
- dung-cake used for cooking has significant variation between the agro-climatic zones, and
- the variation in agricultural residues for cooking between agro-climatic regions is inconclusive.

Table 3.18. Household consumption of fuels for cooking and lighting enduses (useful energy and physical units) (1991)

State	FW[a] (kcal/hh/d)	DC[b] (kcal/hh/d)	AR[c] (kcal/hh/d)	KR(C)[d] (kcal/hh/d)	KR(L)[e] (kcal/hh/d)	Electricity (kcal/hh/d)	FW (kg/hh/d)	DC (kg/hh/d)	AR (kg/hh/d)	KR(C) (l/hh/d)	KR(L) (l/hh/d)	Electricity (kWh/hh/d)
Andhra Pradesh	3353.50	922.71	2410.70	853.26	366.72	188.20	7.04	2.92	5.72	0.28	0.11	0.31
Arunachal Pradesh	4929.01	345.27	854.37	34.25	785.24	60.20	10.4	1.10	2.04	0.01	0.23	0.10
Assam	4935.37	344.79	853.18	34.25	785.24	60.20	10.4	1.10	2.04	0.01	0.23	0.10
Bihar	2905.93	547.08	659.05	152.27	930.30	504.80	6.11	1.76	1.60	0.06	0.27	0.84
Chandigarh	901.95	980.39	782.19	289.19	192.33	180.60	1.92	3.14	1.87	0.11	0.06	0.30
Dadra and Nagar Haveli	2205.06	395.69	713.32	435.68	433.78	240.80	4.62	1.27	1.71	0.11	0.13	0.40
Daman	2272.34	397.14	716.10	435.69	433.78	240.80	4.79	1.27	1.71	0.11	0.13	0.40
Delhi	911.12	982.27	783.71	289.19	192.33	180.60	1.92	3.14	1.87	0.11	0.06	0.30
Diu	2271.88	396.90	716.10	435.69	433.78	240.80	4.79	1.27	1.71	0.11	0.13	0.40
Goa	2317.47	273.85	274.72	1261.37	374.98	180.60	4.4	0.88	0.66	0.39	0.11	0.30
Gujarat	2202.87	389.82	702.78	435.66	433.78	240.80	4.62	1.27	1.65	0.13	0.13	0.40
Haryana	959.50	978.61	780.79	289.18	192.33	180.60	2.04	3.14	1.87	0.08	0.06	0.30
Himachal Pradesh	2656.75	287.84	317.07	1394.50	11.42	120.40	5.61	0.94	0.77	0.40	0.003	0.20
Jammu and Kashmir	2799.56	293.43	323.23	1394.57	11.42	120.40	5.89	0.94	0.77	0.40	0.003	0.20
Karnataka	2409.20	401.75	1604.50	1425.49	329.64	230.53	5.06	1.27	3.80	0.41	0.10	0.38
Kerala	2425.00	274.97	275.85	1261.38	374.98	180.60	5.11	0.88	0.66	0.36	0.11	0.30
Madhya Pradesh	4529.59	577.64	700.24	344.22	438.14	207.83	9.52	1.82	1.65	0.10	0.13	0.35
Maharashtra	2813.76	275.65	982.21	308.11	355.46	180.60	5.94	0.88	2.37	0.09	0.10	0.30
Manipur	4899.91	344.94	853.57	34.25	785.24	60.20	10.34	1.1	2.04	0.01	0.23	0.10
Meghalaya	4941.43	345.19	854.17	34.25	785.24	60.20	10.4	1.1	2.04	0.01	0.23	0.10
Mizoram	4846.80	342.98	848.71	34.25	785.24	60.20	10.23	1.1	2.04	0.01	0.23	0.10
Nagaland	4935.82	345.26	854.35	34.25	785.24	60.20	10.4	1.1	2.04	0.01	0.23	0.10
Orissa	6711.87	744.70	1750.00	34.23	524.59	152.18	14.14	2.37	4.18	0.01	0.15	0.25
Pondicherry	4485.94	1562.83	3101.16	72.30	426.52	120.40	9.46	4.95	7.37	0.02	0.12	0.20
Punjab	965.23	979.98	781.88	289.19	192.33	180.60	2.04	3.14	1.87	0.08	0.06	0.30
Rajasthan	2025.53	1069.62	527.91	422.55	340.43	226.26	4.29	3.41	1.27	0.12	0.10	0.38
Sikkim	4759.72	342.89	848.49	34.25	785.24	60.20	10.01	1.1	2.04	0.01	0.23	0.10
Tamil Nadu	3509.59	1007.75	2428.86	724.39	378.39	175.05	7.37	3.19	5.78	0.21	0.11	0.29
Tripura	4952.96	345.27	854.37	34.25	785.24	60.20	10.45	1.1	2.04	0.01	0.23	0.10
Uttar Pradesh	1052.83	1561.78	331.68	401.22	574.67	633.89	2.2	4.95	0.77	0.12	0.17	1.05
West Bengal	2926.36	860.30	1331.15	374.28	733.71	65.00	6.16	2.75	3.19	0.11	0.21	0.11
All India	2816.35	808.94	1066.09	474.60	516.83	293.10	5.94	2.59	2.42	0.14	0.15	0.49

[a]firewood [b]dung-cakes [c]agricultural crop residue [d]kerosene (C—cooking) [e]kerosene (L—lighting)

The national level aggregates of different estimates of rural household energy consumption are presented in Table 3.19.

Table 3.19. Different national estimates of biofuel consumption in the rural household sector in million tonnes per annum (Mt/a)

	Fuelwood	*Dung-cake*	*Crop residues*
NCAER	93.3	83.2	36.7
REDB (low)	181.3	40.1	31.6
REDB (average)	252.1	106.9	99.2
REDB (high)	309.4	114.5	165.5
IREP	169.0	54.2	62.8

Of the three estimates, though the REDB estimates appear to be consistently higher, the state-wise aggregates indicate that there is no such clear pattern. For example, the REDB estimates for fuelwood are higher largely due to high consumption in the states of Andhra Pradesh, Madhya Pradesh, Orissa, Tamil Nadu and West Bengal. The IREP estimates for fuelwood on the other hand, are substantially higher for the states of Gujarat, Kerala, and Uttar Pradesh. Similarly, dung-cake estimates of NCAER for Bihar and Madhya Pradesh are substantially higher than either the IREP or the REDB estimates.

Some of the likely reasons for the variations and the possible ways that more consistent demand estimates could be made are:

- NCAER data refer to the base period of 1979 whereas the IREP and REDB data are for the period 1985–91. On surface, it would appear that biofuel use in rural areas has increased over time since NCAER estimates are consistently lower than either IREP or REDB data. However, this is more probably due to the difference in the nature of data as described above. The relative closeness of IREP and REDB estimates suggests that there is a need to recast NCAER data according to agro-climatic regions which would require district-wise classification of the surveys,
- experience indicates that variation in the biofuel use is an inherent characteristic of energy systems based on biomass even within an agro-climatic region. The need for an operational classification of agro-climatic regions makes it impossible to capture all factors which may influence biofuel consumption, particularly since the classification is used largely for planning agricultural development. There is, therefore, a need to specify the statistical variation in data collected through surveys and to use these in making demand estimates so as to make different estimates comparable.

Agriculture

Agriculture has been, and continues to be, the mainstay of the Indian economy and is the main source of livelihood for nearly 70% of the country's workers. Over the period, 1950/51–1992/93, the population grew at an average annual rate of 21.6% but the net sown area increased at a mere 0.4%. Quite obviously, the demands of an increasing population would have to be met through an increase in cropping intensities and an intensification of input use in order to boost yields. Thus, while gross cropped area increased at a rate of 0.8%, net and gross irrigated areas increased at 1.9% and 2.4% respectively. Fertilizer consumption increased from 0.6 kilograms/hectare (kg/ha) in 1950/51 to 66.6 kg/ha over the same period.

There has also been a swift transformation in the country's agricultural scenario consequent to the Green Revolution of the mid-sixties. Modern technology, involving the use of high yield variety (HYV) seeds; expansion of irrigation facilities; increased use of fertilizers and agrochemicals; and rapid mechanization, have made it possible to achieve very high crop yields. The introduction of HYVs was particularly successful in the case of rice and wheat, which together account for nearly 63% of the total irrigated area in the country (1990/91). As a result, the magnitude of energy consumption[2] in Indian agriculture has been increasing steadily over the years; although the extent of mechanization and energy intensity are still far less than in developed countries. Trends in energy consumption in agricultural section are presented in Table 3.20.

Table 3.20. Trends in energy consumption in the agricultural sector

Year	*Total electricity use (GWh)*	*Share of agriculture in total electricity use (%)*	*Total petroleum products (Mt)*
1970/71	4470	9.2	—
1981/82	15 396	—	0.302
1991/92 (Provisional)	58 788	24.3	0.587

Sources
1/ Adapted from Energy Conservation in Agriculture Sector, J N Maggo, *TERI Information Digest on Energy*, Vol. 1 No. 4, October–December, 1991, p. 17
2/ Tata Energy Research Institute (TERI), 1992

Another factor contributing to the increased use of energy has been the high incidence of droughts since the mid-sixties. The country has experienced drought conditions in almost all the years from 1965–1974, barring 1967, 1970 and 1973; the 1980s experienced near-severe drought conditions in 1982 and 1985, and a severe drought in 1987. Over the past two decades, consumption of electricity in agriculture has grown at the rate of 13% per annum, whereas oil consumption has increased at the rate of 6 per cent per annum over the last decade (TERI Energy Data Directory and Yearbook—1990/91, New Delhi). At the end of March, 1994, the agricultural sector accounted for nearly 30% of the country's electricity consumption and about 1.3% of the diesel consumed in the country.

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[2] Energy inputs into the agricultural sector are in two forms — animate and commercial The animate energy inputs are in the form of human and animal labour The main sources of commercial energy are electricity and diesel The predominant enduses which directly consume energy in agriculture (commercial and/or non-commercial) are land preparation, irrigation, interculture operations and harvesting. Seeds, organic manure, chemical fertilizers, pesticides and the like, can be considered as indirect energy inputs since they require substantial amounts of commercial energy inputs during production or manufacture.

Increase in the use of electricity as compared to diesel use has come about because of the deliberate policies of the government such as supply of cheap electricity to farmers and pumpset energization (rural electrification). The decision taken by most of the state governments to have a subsidized flat rate tariff on electric pumpsets based on horse power rating led to an increase in the number of irrigation pumpsets (Table 3.21) as well as their utilization. Thus, electricity consumption per pumpset increased from 2743 kilowatt hours per year (kWh/year) in 1970/71 to 5271 kWh/year in 1989/90 (TERI Energy Directory and Yearbook—1990/91, New Delhi). By March 1993, 84% of the villages had been electrified and the number of pumpsets/tubewells energized was about 9.6 million. However, an important side effect of the policies is that there is inefficient and wasteful use of electricity since there is no built-in incentive for conserving energy. This has a dual impact on the environment. The supply of electricity to the agricultural sector entails high transmission and distribution losses leading to a larger generation requirement for each unit usefully consumed. It also leads to acceleration in the rate of ground water depletion.

Table 3.21. Progress of farm mechanization in India (1970–1993)

	1970	*1980*	*1988*	*1993*
Gross cropped area (Mha)	165.8	169.7	177.0	183
Tractors				
Cumulative totals (million)	0.1	0.473	1 054	1 8
Per million hectares of gross cropped area	610	2790	5950	9860
Oil engines				
Cumulative totals (million)	—	2.654	4.250	5 2
Per million hectares of gross cropped area	—	15640	24000	28490
Irrigation pump, electrically operated tubewells				
Cumulative total (million)	1 354	3.965	7.000	9 620
Per million hectares of gross cropped area	8340	23360	39950	52710
Consumption of power (kWh) for irrigation per thousand hectares of gross cropped area	23.3	79.5	196.7	350.7

Source. Centre for Monitoring Indian Economy Pvt. Ltd.(CMIE), (1994)

The rapid increase in mechanization referred to earlier, is evident from the substantially increased use of tractors, diesel engines and electric motors. Tractorization has progressed from 610 tractors per million hectares of gross cropped area in 1970 to

9860 in 1993. This increase has taken place despite the fact that the average size of an operational holding has fallen, and the number of small and marginal farmers has increased.

Tractors are being used for a variety of jobs like tillage, sowing, weeding, harvesting, transport and for stationary jobs like irrigation, threshing, chaff cutting etc. Their use by small and marginal farmers on custom hire basis is increasing, especially for tillage, harvesting and other operations earlier performed manually or by use of animal power.

Diesel engines and electric motors are used mainly for water lifting and to a limited extent for stationary operations like threshing, grain cleaning, milling, crushing etc. The number of electric pumps increased from 1.35 million in 1970 to 9.62 million in 1993. The population of oil engines was 5.2 million by 1993. The increase in the number of electric pumps and oil engines has led to an increase in the consumption of power for irrigation from 23.3 kWh per thousand hectares in 1970 to 350.7 kWh in 1993. Presently, the total population of diesel and electric pumpsets is estimated at 13 million. The annual sale of electric pumps is more than 600 000 and that of diesel pumpsets varies from 350 000–400 000.

Despite the increase in mechanization, Indian agriculture continues to be dependent to a great extent (about 25%) on animal energy for various operations. Animal power has traditionally been the chief source of power for major farm operations like tillage, sowing, interculture, threshing and water lifting. Human labour accounts for almost 10% of the energy used for farm operations. Table 3.22 shows the capacity and numbers of various sources of farm power in India.

Table 3.22. Contribution of various energy sources to farm power (1991/92)

Source of farm power	*No (million)*	*Total (GW)*	*% of Total*
Humans			
Males	149.2	8.95	7.32
Females	50.8	2.54	2.08
Draught animals	84.0	31 50	25.76
Tractors	1.3	29.10	23.80
Power tillers	0.09	0.54	0.44
Diesel engines	4.60	17.16	14.04
Electric motors	8.3	30.96	25.32
Combines	0.044	1.51	1.24

Source Energy Perspectives–Norms and Scenario in Agriculture, G. Singh, *Journal of Rural Energy*, Vol. 1 No. 1, March, 1992

Indirect energy inputs

Growth in indirect energy use in agriculture has also resulted from rapid increases in the use of pesticides and fertilizers. Fertilizer consumption increased from 2.25 Mt in 1970/71 to 13.85 Mt in 1993/94 [Fertilizer Association of India (FAI), 1994.] The annual compound growth rates of nitrogenous, phosphatic and potassic fertilizers over the period 1969/70–1993/94 were estimated at 8.5, 8.9 and 6.7% respectively. It must be borne in mind that fertilizer consumption increases were confined to irrigated areas only, which comprise about one-third of the country's gross cropped area.

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3. Chemical Weekly, October 1992.
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CHAPTER 4

Environmental impacts of energy production and use

There is a growing awareness and common concern in the world about the increasing degradation of the global environment. The recent Earth Summit held in June 1992 at Rio de Janeiro where representatives of more than 170 countries of the world, including Heads of State and Government from 115 countries participated, was the culmination of a series of UN conferences, the first one of which was held in Stockholm in 1972. While winding up the most important debate ever on the state of the world's environment, Maurice Strong, Secretary General, UNCED said, *After Rio, there is greater awareness about the importance of a new contact between* Man and Nature. The attitude of all nations in relation to the environment will be different after Rio '92.

Environmental concerns are high on today's policy agenda. As such, the environment-related impacts of different energy systems are emerging as significant issues for the coming decades. This interest is highlighted by the current debate about effects of pollution on health, environmental damage due to acidification of forests and lake, concern about the safety of nuclear power plants, radioactive waste management, and the potential risk of global climate change induced by increasing atmospheric concentration of carbon dioxide and other greenhouse gases.

Environmental impacts of the energy sector can be classified broadly as, local and global, and those emanating from production (including conversion and delivery) and consumption cycles. In the global context, a comparison of the CO_2 budget for India *vis-a-vis* the global budget, indicates that the total Indian contribution from various sources is about 2.2% of global emissions. The current gross emissions per capita in India are 0.2 teragrams per year (Tg/year) against the world average of 1.2 Tg/year. Various estimates of emission inventory for India are summarized in Table 4.1. Unfortunately, with the exception of atmospheric pollutants, it is very difficult to quantify and aggregate the environmental impacts of the energy chain. As such, while a qualitative description of various environmental impacts is provided, an attempt at quantification has been made largely in relation to atmospheric pollutants.

In India, air pollution is a serious and widespread problem. Much of the air pollution problems in the country are restricted to the urban areas—where, automobiles are the major contributors—and to a few other areas with a concentration of industries and thermal power plants. The rural areas, by and large, are only subjected to air pollution in

Table 4.1. Comparison of different national green house gases (GHG) emission estimates for India

Gas/source	*Total emissions*			*Total absorption*
	Mitra *(1989/90)*	*TERI* *(1989/90)*	*Ravindranath* et al *(1986)*	*Ravindranath* et al *(1986)*
Carbon dioxide (CO_2-C, Tg[a], C/Yr)				—
Coal combustion	99 30	116 900	—	—
Oil combustion[1]	41 40	44 100	—	—
Gas combustion	6 50	6 500	—	—
Cement	5 60	6 300	—	—
Biomass combustion	42 50	—	—	—
a Deforestation	0 30	—	—	—
b. Shifting cultivation	5 40	—	1 6	—
c Accidental fires	19 80	—	32 0	—
d Controlled burning	0 60	—	—	—
e Firewood burning	9 00	—	—	—
f Release soil	0.96	—	3 9	—
g Biomass decomposition	Not included	—	18 8	—
h Long/short use of forestry	7.47	—	7 3	—
• Past LT use	X	—	1 4	—
• Past ST use	X	—	3 1	—
• Current ST use	X	—	2 8	—
Sub-total	42 50	—	63.6	68 9
Total	195 00	174.000	—	—
Methane (Tg, CH_4/Yr)				—
Paddy fields	3-6 (4 0)	3 900	—	—
Livestock	7 00	6 900	—	—
Coal mining	0.40	0 350	—	—
Gas venting, leaking		0 150	—	—
Landfills	1 70[2]	2 400	—	—
Biomass burning	3 40[2]	—	—	—
	2 00[3]	—	—	—
Wetlands				—
Total	16 00	14.000	—	—
Nitrous oxide (Tg, N_2O/Yr)	—	—	—	—
Combustion	—	—	—	—
a Coal	—	0 040	—	—
b Oil	—	0 010	—	—
c. Gas	—	0 002	—	—
Fertilizer use	—	0 012	—	—
Total	—	0 064	—	—
Carbon monoxide (Tg, CO/Yr)	—	35 200	—	—
Biomass combustion	—	35 200	—	—
Chlorofluorocarbon (Tg, CFC/Yr)	—	0 082	—	—

[a] teragrams or million tonnes

Notes

1/ Includes oil used in transport sector

2/ From Organization for Economic Co-operation & Development (OECD) conversion factor

3/ US-EPA

Source Mitra, A.P (1993), Ravindranath et *al*, cited in Gadgil, M (1993), and TERI (1993) Cited in Climate Change in Asia India Country Report Regional Study on Global Environmental Issues Asian Development Bank July 1994 the form of dust and health hazards through the smoke emitted by inefficient *chulhas*. The major sources of air pollution in the country are industries (toxic gases); thermal power plants [flyash and total suspended particulate (TSP)]; motor vehicles [carbon monoxide, lead and particulate matter (NO_x)]; and by the burning of other fuels in domestic stoves.

Before looking at the specific contribution of energy-related activities to pollution, the next few paragraphs provide a broad overview of the institutional and legislative structure relating to the environment.

Environmental institutional structure

The institutional framework for environmental management in India was initiated when the National Committee on Environmental Planning and Coordination was set up in 1972 in the context of the Stockholm Conference. Based on the recommendations put forth in the Tiwari Committee Report, a Department of Environment was created in 1980. The function of the Department was to:

- act as a nodal agency for environmental protection,
- carry out environment appraisals of development projects, and
- have administrative responsibilities for pollution monitoring and regulations.

The functions hitherto performed by the Science and Technology Ministry were transferred to this newly created department. Later in 1985, the subjects of forests and wildlife were also brought together and a Ministry of Environment and Forests (MOEF) was created. A National Committee of Environmental Planning is attached to the Ministry in an advisory role[1].

There are several organizations supporting the MOEF such as, the Central Pollution Control Boards (CPCB), the Botanical Survey of India, the Zoological Survey of India and the Forest Research Institutes, which aid the Ministry in implementation of the Environment Protection Act (EPA), 1986, and primary research areas and environmental conservation/protection.

Almost all the States have also established Environment Boards and Departments, which undertake pollution control and monitoring environmental protection programmes.

Environmental legislation at the national level

Constitutional provisions

For the first 30 or years so of independent India, there was no mention or interpretation of environmental concerns in the Constitution. In 1976, Parliament passed the Constitution (42nd Amendment) Act. Part IV of this Act deals with the directive principles of State policies; Article 47 says: *the State shall regard the raising of the level of nutrition and the standard of living of its people and the improvements of public health as among its primary duties.....* This article provides for the improvement of public health as one of the primary duties of the State and it could very well include by implication, the protection and improvement of the environment, for, the control and prevention of environmental pollution necessarily and primarily comes within the concept of the improvements of the Act. Section 10 of this 42nd Amendment Act says: "After Article 48 of the Constitution the following Article shall be inserted, namely—*Protection and improvement of environment and safeguarding of forests and wildlife*—The State shall endeavour to protect and improve the environment and to safeguard the forests and the wildlife of the country".

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[1] India's Urban Environment—A Status Report, Managing Urban Environment in India· Towards an Agenda for Action, vol 1, TRF, 1993

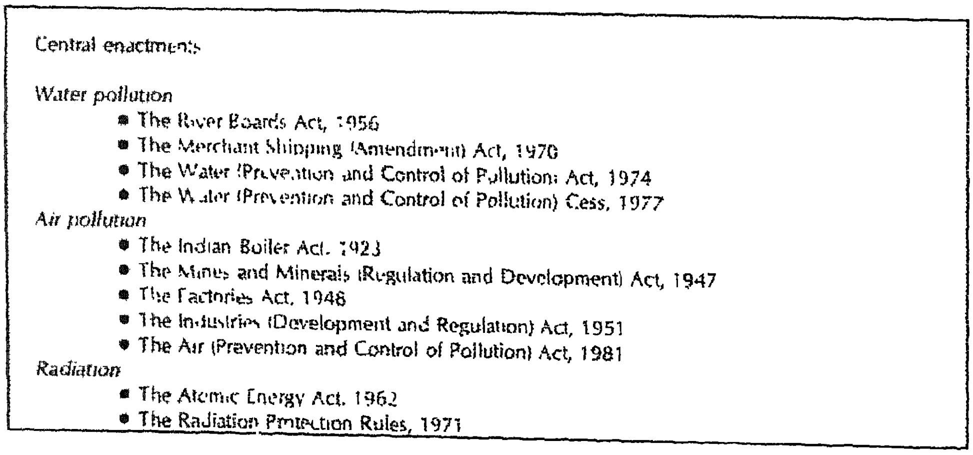
Protection of the environment and promotion of ecological aspects has been included as the Twelfth Schedule to the Constitution which was added by the Constitution (74th Amendment) Act, 1992. This Amendment Act was passed in lieu of democratic decentralization.

Environmental legislation framework

With the backdrop of environmental duties of every citizen expressed in the Constitution, a legal framework is essential to ensure that the constitutional requirements are abided. A strong legislative framework is also required if India's directional development is to be sustained. There are several specific and general Acts/Rules/Laws that have been in effect since before Independence.

There are several State enactments that cover environmental issues such as smoke, noise, pests, land utilization and improvement, apart from the above Central enactments. Some of the major environment-related legislations, given in Box 4.1 and Box 4.2, provide some salient details of the EPA 1986.

Box 4.1



Central enactments

Water pollution

- The River Boards Act, 1956
- The Merchant Shipping (Amendment) Act, 1970
- The Water (Prevention and Control of Pollution) Act, 1974
- The Water (Prevention and Control of Pollution) Cess, 1977

Air pollution

- The Indian Boiler Act, 1923
- The Mines and Minerals (Regulation and Development) Act, 1947
- The Factories Act, 1948
- The Industries (Development and Regulation) Act, 1951
- The Air (Prevention and Control of Pollution) Act, 1981

Radiation

- The Atomic Energy Act, 1962
- The Radiation Protection Rules, 1971

Box 4.1 contd...

Pesticides

- The Poisons Act, 1919
- The Factories Act, 1948
- The Insecticides Act, 1968

Others

- The Indian Fisheries Act, 1897
- The Indian Forest Act, 1927
- The Prevention of Food Adulteration Act, 1954
- The Ancient Monuments and Archeological Sites and Remains Act, 1958
- The Wildlife (Protection) Act, 1972
- The Urban Land (Ceiling and Regulation) Act, 1976
- Forest Conservation Act (1980)

Recent legislation

- The Environment (Protection) Act, 1985
- The Public Liability Insurance Act [illegible], 1991
- Central Ganga Authority
- The Gazette Notification on environmental audit issued in March 1992 has been amended
- Amendments to manufacture, storage and import of Hazardous Chemical Rules have been finalized
- Amendments to Hazardous Waste (Management and Handling) Rules, 1989 have also been finalized
- A Notification regarding authorization of various agencies under Sections 13 and 18 of the PLI Act has been issued
- A fresh Coastal Zone Regulation Notification containing certain amendments has been issued and suggestions from the public have been invited

Box 4.2

Environment (Protection) Act, 1986—Extracts

Since the enactment of the EPA 1986, many steps have been taken by the MoEF to provide the legal and institutional basis which include framing of rules, notification of standards, delegation of powers, identification of agencies for hazardous chemicals management and setting up of environmental protection councils in the States. The EPA is an umbrella legislation and some of the major inclusions in the EPA, 1986 are detailed below.

- The rules under the Water and Air Act have been amended and as per these amendments, the consent order issued by the respective SPCBs to the industries would be valid for a period of 15 years or till such time as there is some significant change in the process— whichever is earlier. No conditional consent would be issued by the SPCBs without complete installation of the required pollution control equipment.
- The Gazette Notification on environmental audit issued on 12th March, 1992 has been amended *vide* Notification GSR 386 (E) dated the 22nd April, 1993. The Notification applies to all the units seeking consent under the Water Act, 1974, or Air Act 1981 or authorization under the Hazardous Wastes (Management and Handling) Rules, 1989. Beginning from 1993, all units are required to submit environmental statements for the period ending 31st March on or before 30th September every year to the concerned SPCBs.
- A Notification consolidating all the environmental standards including general effluent, emission and noise standards has been issued under the EPA 1986. This Notification also includes standards for waste water generation in respect of 11 categories of industries.

Box 4.2 contd...

- A Bill to provide assistance for the setting up of national environment tribunals and expeditious disposal of cases regarding payment of compensation to the victims of accidents occurring while handling hazardous substances was introduced in Parliament in August, 1992.
- Amendments to Manufacture, Storage and Import of Hazardous Chemicals Rules have been finalized. Safety audit in major accident hazard units will now become mandatory with the notification of these Rules.
- Rules for classification, labelling and packaging of hazardous chemicals are being finalized.
- Amendments to Hazardous Waste (Management and Handling) Rules, 1989 have been finalized and are being notified.
- The Forest (Conservation) Rules, 1981 have been amended to further decentralize and streamline the examination of proposals received under the Forest Conservation Act, 1980.
- The Indian Forest Act, 1927 is proposed to be revised and a draft of the revised legislation has been circulated among the State Governments for their comments
- The notification making environmental impact assessment statutory for 29 different activities in industries, mining, irrigation, power, transport, tourism, etc. was issued on 27th January, 1994 by the Ministry. The notification deals with the details of procedures for obtaining environmental clearance, constitution of expert committee, procedure for public hearing and a time schedule for taking a decision.

The Government of India (GOI) has issued strict guidelines, requiring the industries to obtain *no objection certificate* (NOC) from the concerned State Pollution Control Boards (SPCBs), before an industrial license is converted into a *letter of intent* (LOI). While the Ministry of Environment and Forests (MoEF) is the nodal ministry for the implementation of pollution-related provisions of the Environment Protection Act 1986, the CPCB and SPCBs are statutory authorities entrusted with the responsibility of implementing the Water and Air Pollution Control Act. Also, several other enactment powers which have been delegated to the authorities from time to time.

CPCB has been vested with powers to take over the functions of the SPCBs in specific cases, in the event of inaction despite specific directions. The CPCB, being the authority for implementing policies formulated by the MoEF, also has the powers to frame implementation strategies for pollution control, the most important of which is the development of the minimal national standards (MINAS).

The ambient air quality standards were revised recently and the new ambient air quality standards, which came into enforcement from May 1994, are given in Table 4.2.

In order to maintain the ambient air quality at the desirable level, one of the responsibilities of the CPCB is to evolve emission regulations for air-polluting industries under Section 54 of the Air Act, 1981 to control air pollution at source. Emission standards for 12 out of 20 such industries, have been developed.

Notification on Environmental Impact Assessment (EIA) of development projects

Under the Environment (Protection) Act, 1986, the Ministry of Environment and Forests (MoEF), Govt. of India had issued a notification dated 27th January 1994 (amended on 4th May 1994) on EIA of development projects. According to this, any person who

Table 4.2. New ambient air quality standards (May 1994)

Pollutant	Averaging time	*Types of areas*		
		Industrial	*Residential*	*Sensitive*
Sulphur dioxide (SO_2)	Annual average*	80 $\mu g/m^3$	60 $\mu g/m^3$	15 $\mu g/m^3$
	24 hours**	120 $\mu g/m^3$	80 $\mu g/m^3$	30 $\mu g/m^3$
Oxides of nitrogen as NO_x	Annual average*	80 $\mu g/m^3$	60 $\mu g/m^3$	15 $\mu g/m^3$
	24 hours**	120 $\mu g/m^3$	80 $\mu g/m^3$	30 $\mu g/m^3$
Suspended particulate matter	Annual average*	360 $\mu g/m^3$	140 $\mu g/m^3$	70 $\mu g/m^3$
	24 hours**	500 $\mu g/m^3$	200 $\mu g/m^3$	100 $\mu g/m^3$
Respirable particulate matter (size less than 10 μm)	Annual average*	120 $\mu g/m^3$	60 $\mu g/m^3$	50 $\mu g/m^3$
	24 hours**	150 $\mu g/m^3$	100 $\mu g/m^3$	75 $\mu g/m^3$
Lead	Annual average*	1.0 $\mu g/m^3$	0.75 $\mu g/m^3$	0.50 $\mu g/m^3$
	24 hours**	1.5 $\mu g/m^3$	1.00 $\mu g/m^3$	0.75 $\mu g/m^3$
Carbon monoxide	8 hours**	5.0 mg/m^3	2.0 mg/m^3	1.0 mg/m^3
	1 hour	10.0 mg/m^3	4.0 mg/m^3	2.0 mg/m^3

*Annual arithmetic mean of minimum 104 measurements in a year taken twice a week, 24 hourly, at uniform interval **24 hourly/ 8 hourly values should be met 98% of the time in a year. However, 2 per cent of the time, it may exceed but not on two consecutive days

Notes

1/ National ambient air quality standard: The levels of air quality necessary with an adequate margin of safety, to protect public health, vegetation and property

2/ Whenever and wherever two consecutive values exceeds the limit specified above for the respective category, it would be considered adequate reason to institute regular/continuous monitoring and further investigations

3/ The State government/State Board shall notify sensitive and other areas in the respective states within a period of six months from the date of notification of National Ambient Air Quality Standards

Source. CPCB, New Delhi (1994)

desires to undertake any new project or the expansion or modernization of any existing industry or project listed in Schedule I (See Box 4.3) of this notification shall submit an

Box 4.3

Schedule I. List of projects requiring environmental clearance

- Nuclear power and related projects such as heavy-water plants, nuclear fuel complex, rare earths
- River valley projects including hydel power, major irrigation projects and their combinations including flood control
- Ports, harbours, airports (except minor ports and harbours)
- Petroleum refineries including crude and product pipelines
- Chemical fertilizers (nitrogenous and phosphatic, other than single superphosphate)
- Pesticides (technical)
- Petrochemical complexes, petrochemical intermediates and production of basic plastics
- Bulk drugs and pharmaceuticals
- Exploration for oil and gas and their production, transportation and storage
- Synthetic rubber
- Asbestos and asbestos products
- Hydrocyanic acid and its derivatives
  (a) Primary metallurgical industries
  (b) Electric arc furnaces (mini steel plants)
- Chlor-alkali industry
- Integrated paint complex including manufacture of resins and basic raw materials

Box 4.3 contd...

- *Viscose staple fibre and filament yarn*
- Storage batteries integrated with manufacture of oxides of lead and lead antimony alloy
- All tourism projects between 200–500 m of high tide line or at locations with an elevation of more than 100 m with investment of more than Rs 5 crores
- Thermal power plants
- Mining projects (major minerals) with leases more than 5 hectares
- Highway projects
- Tarred roads in the Himalayas and/or forest areas
- Distilleries
- Raw skins and hides
- Pulp, paper and newsprint
- Dyes
- Cement
- Foundries (individual)
- Electroplating

application to the Ministry of Environment and Forests, New Delhi. The application shall be accompanied by a project report which shall include an Environmental Impact Assessment Report/Environment Management Plan prepared in accordance with the guidelines issued by the Ministry of Environment and Forests of Central Government.

The reports submitted with the application will be evaluated and assessed by the Impact Assessment Agency (IAA) which, if deemed necessary, may consult a committee of Experts having a composition as specified in Schedule III of the EIA notification. The IAA would be the MoEF. The committee of experts mentioned above will be constituted by the IAA which will prepare a set of recommendations based on the technical assessment furnished by the project authorities.

Public hearing could be called for, in case of projects involving large displacement or having severe environmental ramifications. Comments of the public may be solicited, if so decided by the IAA, within 30 days of receipt of the proposal, in public hearings arranged for the purpose after giving 30 days notice of such hearings in newspapers.

The assessment shall be completed within a period of 90 days from the receipt of the application form by the project authorities and their decision conveyed within 30 days thereafter.

Environmental issues in coal mining

The magnitude and significance of environmental degradation due to coal mining depends on the method of mining and beneficiation; scale and concentration of mining activity; geological and geo-morphological setting of the area; nature of deposits; land use pattern before the commencement of mining operations; and the natural resources existing in the area. Opencast mining operations pollute the environment much more severely than does underground mining.

Land degradation

The most serious impact of mining operations is on the land use pattern in the area. Earlier, most of the coal mines in India were underground mines and generally restricted to Jharia and Raniganj coalfields. However, after nationalization, coal production has been increasing rapidly and in the last two decades, the incremental production has come from opencast mining. This emphasis on opencast mines has led to degradation of land and displacement of population. Due to the high density of population, acquiring large tracts of land required for opencast mining is difficult and the issue of resettlement and rehabilitation of people gains immense significance. The present rehabilitation package to resettle the displaced persons has not received a favourable response from the land oustees.

Norms for land requirement and displaced populations

The average norms for land requirement, rehabilitation and afforestation cost of coal projects based on an analysis of the sample data of mines and projects have been estimated as given in Table 4.3.

Table 4.3. Norms for land requirement and displaced population (ha per Mt capacity)

	OC[a] Mine	*UC[b] Mine*
Norms for land requirement		
Land requirement/Mt of capacity (ha)	513.00	235
Share in total land of		
a. Forest	0.31	
b. Non-forest	0.69	
Tenancy land per Mt of capacity	124.00	57
Forest land per Mt of capacity	159.00	73
Government land per Mt of capacity	230.00	105
Norms for rehabilitation of families		
Number of families affected/Mt of coal	173.00	32

[a]opencast [b]underground; ha per Mt—hectares per million tonnes

Source. Energy Modelling for India: Towards a policy for commercial energy, Planning Commission, Government of India (1989)

However, the norms would be different for different coalfields depending on geological parameters, capacity of mine, settlement and land-use pattern in the area etc.

Rehabilitation policy

In order to provide effective rehabilitation and resettlement to the displaced population, the guidelines established by the World Bank include:

- adequate compensation for lost assets,
- assistance with relocation and support during the transition period, and
- assistance in re-establishing former living standards.

The guidelines further emphasize that the project design should minimize the need for involuntary re-settlement and that projects should ensure that those who have to move, benefit from the project that displaces them. The objective is to provide a means to improve their standard of living.

Keeping the above points in view, the Government has approved a rehabilitation package for displaced populations *vis-a-vis* the coal industry. The package offers the following benefits to all displaced persons:

- plot of land (0.01–0.02 hectares) for each family in the rehabilitation colony,
- shifting allowance @ Rs 1000–2000 per family,
- lumpsum grant @ Rs 5000 per family,
- economic compensation to land losers, who are not provided with employment, @ Rs 6000 per annum (or Rs 500 per month) for 20 years,
- vocational training to one-third of the population affected @ Rs 10 000 per family, and
- rehabilitation colonies with certain basic facilities such as primary school, dispensary, roads, etc.

In addition, the land losers are entitled to monetary compensation for the land acquired. Employment to one member of the family is given subject to job availability and suitability.

Loss of forest land

The impacts of mining on forest areas is of particular concern in India as there is considerable overlap between tropical forests and mineral reserves. Opencast mining destroys forest land totally. Forest land is, however, normally not released for external dumps and infrastructure facilities. While subsidence has some effect on forest land in underground mines, it is normally not acquired in underground mining areas. When forest land is released for mining the Government of India requires the company to undertake compensatory afforestation on non-forest land.

Environmental cost analysis

Environmental control measures need sufficient funds and efforts to ensure adequate and permanent environmental improvements. The cost of environmental control measures is generally an integral part of the project costs. In 1992/93, TERI had carried out a study to assess the environmental cost in coal mining. The costs were grouped under five major heads and reflect only the cost of direct control measures.

- Cost of rehabilitation of displaced population
- Cost of compensatory afforestation (for forest land acquired)
- Cost of land reclamation which includes technical and biological reclamation

- Cost of anti-pollution measures for control of air, water and noise pollution
- Cost of other provisions like preparation of report, R & D expenditure, etc.

The environmental cost analysis was carried out for 16 opencast mines spread over 10 coalfields (with capacities ranging from 1.75–10 Mt/a) and 8 underground mines spread over 8 coalfields (capacities ranging from 0.15–1.5 Mt/a). In some coalfields, more than one mine was included in the sample. To derive an average environmental cost for the industry as a whole, the production plans of these 13 coalfields for 1996/97 were studied, and the weighted average environmental cost was estimated. The details are given in Table 4.4.

Table 4.4. Coalfield-wise average environmental cost and coal production plan

Coalfield	*Environmental cost (OC mines) (Rs/t)*	*Environmental cost (UC mines) (Rs/t)*[a]	*Production projections 1996/97 (tonnes)*		
			OC	*UC*	*Total*
Ib valley	18.56	—	11.20	1.68	12.88
Talcher	9.24	—	24.90	0.78	24.68
Wardha valley	11.05	6.92	14.95	3.74	18.69
Jharia	20.07	9.14	16.00	16.00	32.00
Singrauli	10.87	—	39.00	—	39.00
East Bokaro	25.40	—	10.21	1.14	11.35
West Bokaro	20.86	—	6.75	0.75	7.50
Ramgarh	18.63	—	2.70	—	2.70
Rajmahal	10.73	—	10.50	—	10.50
North Karanpura	16.09	10.29	13.26	1.47	14.73
Assam	—	21.97	0.40	0.60	1.00
Raniganj	—	12.02	5.00	20.10	25.10
Coal India Limited	—	19.20	14.60	6.30	20.90
Total	12.57	11.37	169.46	52.56	222.02

[a]rupees per tonne

The overall cost of environmental control measures for all mines in these coalfields was calculated, based on the production plan and the weighted average cost of impact for opencast and underground mines. This works out to Rs 12.29 per tonne of coal production and is about 3 per cent of the current average price of coal.

Land degradation in old coalfields

In old coalfields like Jharia, Raniganj and East Bokaro, the past unscientific mining operations have resulted in extensive damage to land and water resources in the area. It is estimated that about 18 000 ha of land has been rendered derelict due to fires, subsidence, open excavation and waste dumps caused by mining operations. The details are given in Table 4.5.

Table 4.5. Land degradation in mining areas (ha)

Area affected by	Raniganj	Jharia	Others	Total
Subsidence	5094	3497	526	9117
Abandoned pits	—	1268	3632	4900
External reject dumps	370	631	100	1101
Fire	600	1732	—	2332
Total	6064	7128	4258	17450

In 1988, the Government of India constituted an expert committee on restoration of abandoned coal mines especially in Jharia, Raniganj and East Bokaro coalfields. The committee, in its report, had recommended a reclamation strategy that does not involve anything more than simple landscaping and greening, without elaborate filling of cavities and depressions except where cracks have appeared and in the fire-affected areas. It had also recommended reclamation of such abandoned mines and subsided areas in which there was livelihood of mining activity in the foreseeable future. The costs of reclamation of about 15 000 hectares of damaged land in these coalfields was estimated at Rs 1100 million (in 1988 prices). The details are given in Table 4.6. The committee had also suggested that this activity could be spread over 5–8 years and funded by the Government. However, the Government has not taken any decision to provide funds and hence there has been no progress on reclamation of damaged lands in these coalfields.

Table 4.6. Estimated costs of reclamation of damaged land

	Raniganj		Jharia		East Bokaro	
Coalfield	Area (ha)	Estimated cost [Rs (Cr)]	Area (ha)	Estimated cost [Rs (Cr)]	Area (ha)	Estimated cost [Rs (Cr)]
Land area affected by fire	600	9.0	1732	69.3	—	—
Subsidence	5094	12.7	3497	10.5	526	1.3
Working mines	—	—	1268	2.5	638	1.3
Water storage areas	138	0.1	—	—	302	0.3
External dump	370	0.8	630	1.3	100	0.2
Total	6202	22.6	7127	83.6	1566	3.1

Land affected by mine fires

The committee had also emphasized that the areas threatened by fires and premature collapse should be dealt with separately through fire projects. In fact, in the Jharia coalfield, 22 fire projects were formulated and sanctioned by the Government for dealing with the fires at an estimated cost of about Rs 200 crores. A sum of Rs 72 crores has already been incurred so far and this has resulted in saving of about 100 Mt of coal reserves from burning. An area of about 2500 hectares of land affected by fire has been reclaimed in the Jharia coalfield during the last decade. The fire projects are continuing and are in various stages of implementation.

Environmental concerns in the hydrocarbon sector

Other than a potential blow out, the major source of environmental concern from hydrocarbon exploration and production is the spillage of drilling fluids into the environment. It is difficult to quantify the magnitude of the impact from such discharges because the dispersion and dilution of such discharges would vary, depending on the ambient water condition, composition of drilling fluids and the rates and duration of drilling and cutting discharges.

Crude production

In the production of crude oil, the principal wastes can be categorized as those arising from drilling and those from production *per se*. The former are of lesser concern, being the drilling muds, additives, cements, well-treating fluids, and flow enhancers for stimulating production. The main waste from production is the brine associated with the oil/gas in the crude-bearing formation or reservoir. It is mostly water with dissolved mineral salts, which also contains dissolved petroleum in small concentrations. After a phase separation at the lease, the brine may be pumped back into the reservoir at points which do not affect production.

Flaring of natural gas

Oil in the reservoir contains various proportions of associated or dissolved gas. Natural gas is used primarily as a feedstock for the fertilizer industry and also as fuel for industry or power generation. The rest of the gas is let off at the tail-end as a flare. About 5 Bcu.m out of a total gross production of about 18 Bcu.m of natural gas was flared in India in 1990/91. Flaring of natural gas has adverse impacts in terms of air pollution in the form of emissions of oxides of sulphur and nitrogen; and carbon dioxide, an important greenhouse gas.

Impacts of crude transportation

In the transport of crude by truck, rail, barge, tanker or pipeline there is a buildup of bottom sediment waste (BSW), which must sooner or later be discharged somewhere. There is also the serious and much-publicized catastrophic probability of oceanic spills. The threat to the marine ecosystem from these cannot be overstated, so much so that sometimes large colonies of fish, and even coral reefs are wiped out. Absorption of large quantities of oil also makes the fish unsafe for human consumption.

Refining

Emissions to the atmosphere from a refinery depend on factors like complexity of operations, types of crude processed, control measures, and maintenance/housekeeping practices. The various pollutants are sulphur oxides, nitrogen oxides, carbon oxides, hydrocarbons, etc.

A comparison of TSP, SO_x and NO_x emitted from a typical 6 Mt refinery and a 1000 MW coal-based power plant would show negligible TSP emissions along with lower levels of SO_x and NO_x. Therefore, a refinery, by itself will not significantly affect air quality. However, a refinery located in an already polluted area is likely to have major environmental impacts. Also, discharge of refinery effluents has an adverse impact on the receiving water body. A 6 Mt refinery discharging into a river of 400 Bcu.m flow will increase the biological oxygen demand (BOD) by approximately 1.5 mg/l. In comparison, a 1000 MW coal-based plant at the same location would have an impact that would approximately be lower by an order of magnitude.

Sulphur, by far the most predominant impurity in crude oil, exists as sulphides, polysulphides and thiopenes. Crudes vary significantly in sulphur content and, therefore, the processing scheme must be able to handle the crude of maximum sulphur content that can be encountered.

Storage facilities are the most significant sources of hydrocarbon emissions. Vapours are emitted when storage tanks *breathe* as also when vapours are displaced during filling, and when liquids evaporate. Floating roof tanks are provided for the storage of high vapour-pressure hydrocarbons to minimize evaporation loss from liquid surface. This can bring about nearly 95% reduction in emissions. Loading gantries, where tank wagons and tank trucks are loaded, also contribute to hydrocarbon emissions. As for hydrocarbon leakage from pumps and compressors, these can be minimized by better maintenance and replacement of gland packing with mechanical seals. Leakages from valves and flanges can be controlled by close monitoring using hydrocarbon detectors and through regular maintenance.

SPM emissions occur predominantly as catalyst fines from catalyst regenerators. In typical installations, 2 or 3-stage cyclones are located in regenerator vessels of fluidized Catalytic Convertor (FCC) units for catalyst recovery. As a control measure, electrostatic precipitators (ESPs) are used in a few refineries to collect fine particles from regenerator exit gases.

Sources of CO include catalyst regenerators, coking operations, boilers and process heaters. Catalyst regenerators in FCC units emit significant amounts of CO which can be burnt in CO boilers. CO emissions from boilers and heaters can be eliminated by ensuring proper combustion of fuel. There are twin benefits of using CO boilers: the CO is burned to CO_2 and the heat of combustion is also utilized for producing steam. The emission of CO_2 should not be viewed as increase in the existing levels of CO_2 in the atmosphere, rather, it is purely an improvement in the efficiency of use of an energy form leaving net CO_2 addition levels undisturbed.

Refinery waste water typically contains oil, phenols, sulphides, dissolved and suspended solids which originate from process operations, storage tank water drainage, cooling tower blow down etc. Other liquid chemical wastes are mainly acidic and alkaline effluents from petroleum product treatment units. Improvement in product treating methods such as MERcaptan Oxidation (MEROX) units have obviated the need for treating units using sulphuric acid.

Waste water is subjected to elaborate treatment in state-of-the-art effluent treatment plants (ETPs). These comprise physical, chemical and biological processes to upgrade the quality of effluent water so that it can be safely discharged into surface water or recirculated to the refinery.

Solid waste generated during refinery operations consists mainly of oily sludge from storage tank bottoms and oil separators, and chemical and biological sludge from ETP facilities.

Hot gas/oil circulation facility/side entry mixers have been provided in most of the crude oil tanks at refineries and pipeline installations to minimize oily sludge generation and to recover additional oil. Oily sludge is treated in the melting pits for the recovery of oil. Leftover sediments/dry sludge is disposed off by landfilling within refinery premises. Chemical and biological sludge, after neutralization/natural degradation in drying beds, is also disposed of by landfilling. Land treatment/sludge farming techniques for more efficient disposal of residual sludge are under experimentation at certain refineries.

Pollution control in the refineries

Pollution control/environmental protection is considered to be an integral part of the refining operations in the country. In recent times, especially after the enactment of the Environment Protection Act in 1986, statutory requirements have become stricter, and accordingly, the refining sector has been gearing itself towards the upgradation of existing treatment systems/control techniques and monitoring facilities. MINAS for liquid effluents, and air-emission standards have been evolved by the CPCB for major categories of water and air polluting industries, including oil refineries. These refer to the maximum concentration of pollutants in effluents discharged into a water body or emissions that may be discharged into the atmosphere. The emission standards for oil refineries are shown in Table 4.7.

With a view to secure nationwide compliance with these prescribed standards, task forces have been constituted by the CPCB for major categories of industries. The status of pollution control in the refining industry, as emerging from the deliberations of task forces, is provided below:

• total number of oil refineries in the country,	12
• number of units complying with both MINAS and emission standards,	01
• number of units complying with MINAS,	05
• number of units complying with emission standards.	03

Ambient air quality

Along with the control and monitoring of emissions from refineries, ambient air quality monitoring in and around refinery locations is regularly carried out in all the Indian refineries. The monitored results indicate compliance with ambient air quality standards in the oil refining sector. In sensitive locations like the Mathura Refinery (due to its proximity to the Taj Mahal). SO_2 concentration levels are continuously monitored in four stations covering a distance of 38 km from the refinery.

Table 4.7. Emission standards for oil refineries

Parameter	*Quality*	*Quantity (kg/1000 t of crude processed)*
MINAS for refinery waste waters		
Basis : Waste-water generation—700 kilolitre/1000 t crude processed		
• Oil and grease (mg/l)	10.00	7.00
• Total suspended solids (mg/l)	20.00	14.00
• BOD @ 20°C (mg/l)	15.00	10.50
• Phenols (mg/l)	1.00	0.70
• Sulphides (mg/l)	0.50	0.35
• pH	should be between	6.0–8.5
Air pollution emissions standard (under EP Act—1986)		
Emissions	Sulphur dioxide	
• Crude distillation (atmospheric plus vacuum) (kg/t of feed)		0.25
Catalytic cracker (kg/t of feed)		2.50
• Sulphur recovery unit (kg/t of sulphur in feed)		120.00

In an effort to minimize the lead level in ambient air due to automobile exhaust, use of tetraethyl lead (TEL) as octane booster in motor spirit (MS) is being restricted. The lead level in MS of 87-Octane is to be brought down to 0.15 gm/lit by 1993/94, by installing new catalytic reforming units.

Development of scientifically designed green belts has also been taken up in most refinery locations. These act as pollution sinks and help in improving ambient air quality.

Occupational health monitoring

Testing of lead level in blood/urine of TEL handlers, work environment monitoring with regard to benzene, hydrogen sulphide (H_2S) and other toxic gases, health checks of employees etc. are presently being done at various refineries. Plans are underway to set up full-fledged occupational health centres at all the refineries, for providing comprehensive occupational health services to the employees.

Electricity

All fuel chains within the electricity production cycle have some form of environmental impacts associated with them. According to recent estimates, these activities contribute to approximately 80% of the total global emissions of carbon dioxide, a major greenhouse gas which is considered to affect global climate change.

Coal-based thermal power stations (TPS)

MoEF *vide* Gazette Notification of 3 January 1989, issued the first amendment rules to the Environment Protection Act, 1986 which stipulated the particulate emission limits for thermal power stations as given below:

• generation capacity 210 MW or more	150 mg/Nm^3
• generation capacity less than 210 MW	350 mg/Nm^3
• units located in protected area	150 mg/Nm^3

The rules do not make any separate stipulation for SO_2 emission standards. The recommended control measures continue to be in accordance with the 1984 regulations through stack height stipulations. Apart from stack height, the regulations also require that, for plants having boilers of 500 MW and above, necessary space be provided for installing flue gas desulphurization units, should there be such a requirement in the future.

With increased opencast mechanized mining, the quality of coal has deteriorated considerably over the last three decades. In 1970, the average calorific value of coal was 5200 kcal/kg and specific coal consumption was 0.63 kg/kWh. The calorific value of coal has deteriorated to around 4000 kcal/kg and the specific coal consumption has increased to 0.7 kg/kWh. The percentage of ash content has also increased from 30–35% to 40–45% during this period.

An important factor in the ash from TPS is the sulphur-to-ash ratio, which is extremely low. While generally the sulphur-to-ash ratio is 1:10, for Indian coals it is 1:100, and sometimes even less, which leads to very high resistance. This value improves marginally when the moisture content of coal is high. Secondly, the low volatile matter

v calorific value of coal requires operation of boilers with higher excess air which
; resistance by decreasing the temperature of the combustion chamber and by a
higher rate of transformation from SO_2 to SO_3.

The dust collection plant obviously has to process a large quantity of ash with a
sistance of the order of 1–5 × 10^{13} Ohm/cm^2. If emissions of 150 mg/Nm^3 are to be
·d, the resulting separation efficiency should be around 99.7% or more.

of pollution control equipment

ısh precipitation systems in new units can be designed according to the latest norms
ch technology and know-how is available indigenously, the systems installed in the
ts were designed in accordance with the technology available and the extent of
.mental awareness at the time these units were designed, engineered and
cted. There are either only mechanical precipitators (MPs) or combination of MPs
PS or only ESPS.

It would require tremendous effort to improve the performance of ash precipitation
; of old TPS to the tune of 99% from the existing efficiency of 85–95%. Space
ons, age of plant, complete reorientation requirement for the auxiliaries (which
nes may not be practical), apart from finance, are some of the hindrances to
g about any change in the existing systems. In thermal units installed during the
and seventies, the existing ash precipitation and connected ash handling systems
be completely replaced with new improved-design, larger ESPS and ash handling
;. This activity being capital-intensive, brings about financial constraints in
ng this objective. In some of the units, replacement is not techno-economically
e and because of acute power shortage in the country, it has not been possible even
e down very old units. For units which have been commissioned during the eighties,
:enovation work and filling up of fields may help in improving the situation.

The installation of ESPS for the control of suspended particulate matter (SPM)
ıons has been made mandatory in India. The average cost of SPM control by ESPS
›roximately 1 per cent of the cost of generation. ESPS usually operate at efficiencies
% and above; the efficiencies are relatively insensitive to particle size but grade
iency curves indicate a minimum in the 0.2–2.0 micrometres range. However, the
ciency of particulate removal below 0.1 micrometer is poor. Since about 95% of the
gas comprises particles with less than 0.1 micrometre diameters, it implies that only
out 5% of the particles are actually removed, though the mass equivalent is about 99%.
his is important, given the smaller sized particles penetrate deeper into the lungs and,
ıerefore, be more toxic.

Mandates for the installation of control equipment for SO_x and NO_x emissions are
yet to be promulgated. For SO_x, post combustion abatement using a flue gas desulphurizer

(with efficiencies in excess of 90%) is an expensive option (about 25–30% of the cost of generation). Given the low levels of sulphur in Indian coals (around 0.5%) and the high associated costs, the installation may be limited to regions already stressed by high levels of SO_x and/or TSP emissions.

Post-combustion NO_x control can be achieved with selective catalytic reducers (SCRs), with efficiencies greater than 80%. Cost of NO_x removal adds about 6 per cent to the cost of generation. The validity of installation of SCRs is primarily dependent on whether lower levels of NO_x emissions are achievable with improved combustion practices. Currently, pre-combustion control options, e.g. low NO_x burners, are being installed in some plants. Though the costs are low (approximately 0.2% of the cost of generation), the removal efficiencies of low NO_x burners is below 50%. Devices used for the control of SO_x and SPM yield solid wastes, wet or dry, that further require disposal.

Water pollution

Water pollution is generally the result of the discharge of boiler blowdown and cooling water into the surrounding water-bodies. The water generally contains chlorine and other BOD material which affects aquatic life adversely. Another impact on the water-body is that as a result of thermal pollution, elevated temperatures of the surrounding water may increase the metabolic rate of aquatic life or may kill some of the more sensitive species. A high metabolic rate in turn would have an impact on the quantity of CO_2 emitted. Further, higher temperatures of the water-body would lead to a greater dissolution of chemicals and other pollutants such as grease leading to greater environmental damage. Water pollution can be controlled significantly if cooling systems, e.g. cooling towers, are adopted prior to the discharge.

The CPCB has set air and water quality standards, but little success has been achieved in enforcing them.

Hydropower projects

The environmental consequences of hydro-electric power projects encompass a wide area that includes the physiochemical, biological and social environment. The environmental and social impacts are a direct result of dam construction and the consequent formation of a reservoir. Among the impacts, the significant ones include:

Displacement of people

This is one of the most important issues associated with large hydro-electric projects. It has acquired great prominence today through a widespread movement by several environmentalist groups all over the world. Some inevitable consequences of the displacement of people are the *loss of tangibles* like houses, private land, forest wasteland, public buildings and places of worship and the *emotional and physical suffering* of the oustees during and after the process of displacement. Although compensation is given, the problems of implementation, and in some cases the rehabilitation package itself, fail to adequately compensate for the loss. Moreover, as past records show, when oustees are rehabilitated they are almost never moved *en bloc*, but are scattered, thus making it more difficult for them to re-establish their community life.

Submergence of agriculture and forest land

The building of a dam, formation of a reservoir, and other construction activity in a vicinity, leads to submergence of large areas of land. Most of the time, very large areas of forest are lost. This is essentially a loss of the services or benefits the forest provides such as timber and other minor forest products, prevention of soil erosion, climate regulation, production of oxygen, absorption of carbon dioxide and provision of a habitat for birds and animals.

Sedimentation of reservoirs

Sedimentation of a reservoir occurs naturally whenever a river carrying sediment is obstructed by a dam. The origin of the sediment is the watershed. Uncontrolled deforestation, overgrazing, and faulty agricultural practices in the watershed accelerate soil erosion resulting in increased sediment flows into the stream and finally into the river. Increased sediment deposits, if not flushed or dredged out, can reduce the storage capacity of the reservoir and, therefore, the life of a dam.

Water-logging and salinity

Increase in waterlogging and salinity is not associated directly with the dam as such, but with the irrigation canals where proper drainage is lacking. Perennial irrigation in most cases raises the water-table because of water seepage from irrigation channels.

Community health

Water impounded behind the dam—more stable with less turbulence—is subject to less sunlight penetration and oxygenation. This increases the survival of disease organisms such as malaria, encephalitis and yellow fever and thus has significant effects on human health.

Nuclear power plants

The hazards from releases of a nuclear plant are distinctly different from the releases from other sources (such as thermal plants), in that they are radioactive. The design of nuclear power plant, however, is such that during normal operation, the releases of radioactivity are negligible. In the event of an accident, however, the consequences are not only limited to the regions in the vicinity of the plant but are also far-reaching both in spatial and in the intergenerational context.

The two key concerns in this sector are regarding long-term waste management and the eventual decommissioning of plants. Wastes generated from a nuclear plant may be classified into three types—low, medium and high level—depending on the level of radio activity. The problem associated with wastes is that of long-term disposal of high level wastes. In addition, disposal of the reactor components at the end of the economic life of a plant also poses problems. This issue is inextricably linked to the concerns about decommissioning. High level wastes like spent fuel and the by-products of fuel reprocessing have to be removed before decommissioning. The spent fuel is highly radioactive and remains more so than the uranium ore for as long as about 3 million years. It requires remote handling. Although the spent fuel can be reprocessed, worldwide nuclear agenda slowdown, tardiness of the breeder programme and concerns about nuclear proliferation have undercut the rationale for reprocessing. The search for sites for disposal of high level wastes has also become a contentious issue.

Industry

There has been a major policy reform in the industrial sector. In the July 1991 Statement on Industrial Policy[2], not only was the compulsory licensing cut to 15 industry subsectors, but industrial siting in relation to major cities was also provided for. Industrial siting will be determined by zoning, land-use regulations, and environmental regulation in accordance with the Statement.

The major environmental concern in the industrial sector—in addition to its contribution to energy demands and hence the need to increase supplies—is its high contribution to the emission loads of cities, since many of the industrial belts/estates are located in or close to the cities. Based on monitored ambient air quality, 18 major polluted regions in the country have been identified where siting of a new industrial unit will be critical.

There are industry-specific emission standards for air pollution. The CPCB has prepared ambient air quality standards for select pollutant parameters as given earlier in this chapter.

In the case of hazardous chemicals, the Government has specified certain threshold quantities within the framework of the Environment Protection Act, 1986. If an industrial installation involves the use of a hazardous chemical in an amount equal to or greater than the threshold quantity, it must comply with certain fuels as specified in the Manufacture, Storage and Import of Hazardous Chemical Rules, 1989.

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[2] Industrial Policies and Development, Economic Survey, 1993–94.

Iron and steel plants

Steel-making comprises a series of high temperature chemical processes involving raw materials such as iron ore, coal, limestone, dolomite etc. Owing to the scale of operations, steel plants are considered *bulk polluters*. However, the nature of pollution is not very intense. Table 4.8 gives the emission standards for the integrated iron and steel industry.

Table 4.8. Emission standards in integrated iron and steel industry

Unit	Particulate emission limit (mg/Nm^3)
Coke oven	50
Refractory material plant	150
Rolling mills	150
Sintering plant	150
Steel melting shop.	
during normal operation	150
during oxygen lancing	400

The causes of air pollution, centre around emissions comprising particulates of iron oxide, limestone, dolomite and coke dust, and from gases such as oxides of sulphur, nitrogen and carbon. Phenolic and cyanide effluents from coke ovens, oil and grease from various process plants and acidic effluents from the pickling lines are the main pollutants of the receiving water bodies around steel plants. The environment is also affected by the generation and discharge of various types of solid wastes. Though steel plants have many areas of high noise within the plant boundary, noise pollution has not been found to be significant in the peripheral areas.

Even at current levels of technology, it is possible to largely contain the above forms of pollution emanating from steel plants. In the past, provisions made towards containing pollution were mainly operation-oriented. In the absence of continued and commensurate technology upgradation, the initial imbalances were aggravated. The systematic approach towards environment management is hence directed towards

- establishing well equipped laboratories with monitoring equipments,
- identification of inadequacies of existing pollution abatement measures installed in the plants,
- incorporation of modern technology in pollution control having relevance to international practices and,
- establishing a strong data base for monitoring temporal trends.

Paper industry

Pulp and paper production places a heavy burden on the environment, through its extensive raw material and energy usage.

Air pollution

Sulphite, Kraft and semi-chemical processes use sulphur, thus emitting sulphuric gas. The fuels used (oil, coal, gas and wood waste) produce varying quantities of ash, soot and smoke. These gases and the sulphuric acid fumes produce a noticeable contamination of the air causing health problems, damage to buildings etc.

Digesters and steam boilers are the main sources of atmospheric pollution. The major gaseous emissions are malodorous reduced sulphur compounds such as hydrogen sulphide, methyl mercaptan, dimethyl sulphide and dimethyl disulphide; oxides of sulphur; and oxides of nitrogen.

The chemical recovery furnace generates SO_2 due to combustion of sulphur-containing black liquor fuel. The malodorous sulphur gases emitted, have extremely low odour threshold levels of between 1–10 parts per billion (ppb) by volume. The concentration of reduced sulphur compounds in the exit gases can be as high as 10 000 ppm. Hydrogen sulphide results from black liquor tripping by steam. Black liquor oxidation forms dimethyl sulphide.

The particulate matter emissions are primarily sodium sulphate and sodium carbonate from the recovery furnace and sodium compounds from the lime kiln and smelt tanks. The main sources of particulate matter are the recovery furnace, lime kiln, smelting tank and power boilers. The recovery furnace is the largest potential source. The particulate emissions constitute Na_2SO_4, with smaller quantities of Na_2CO_3, and NaCl.

Nitrogen oxide is emitted from the recovery furnace and lime kiln and is normally lower than that for most other fuel combustion processes. This is primarily due to the large quantities of water present in black liquor and lime which act as a heat sink to suppress the flame temperature.

Small mills using chemical processes find chemical recovery uneconomical. In agricultural residue-based mills, after the raw material digestion with caustic soda and/or lime is completed, pressure in the digester is released once a temperature of about 90°C is attained. During the process, about 1.4 tonnes of steam per tonne of pulp, containing volatile organics escapes. The escaping gases have a characteristic odour. Small mills do not generate hydrogen sulphide and mercaptan since sodium sulphide is not used in the pulping process. Pollution is confined to the surroundings of the mill and is intermittent due to the batch process adopted. The emission standards of large pulp and paper mills are shown in Table 4.9.

In general, most of the plants do not meet the existing emission standards for particulate matter. Sulphur dioxide emissions are within limits, while hydrogen disulphide exceeds the regulatory limits by several times. The total number of plants that presently have new ESPs is 34.

Table 4.9. Large pulp and paper mills—emission standards

Parameter		Standard	
For recovery boiler capacity	Particulate matter	250 mg/m^3	– H_2S 10 mg/m^3
	Standard for particulate matter concentration		
Lime kiln	Up to 5 tonnes/day	Hood provision	
	More than 5 tonnes/day and up to 40 tonnes/day	500 mg/Nm^3	
	More than 40 tonnes/day	150 mg/Nm^3	

Water pollution

Pulping and paper making consumes as much as 250–450 m^3 of water per tonne of paper in India as against 60–120 m^3 per tonne of paper in developed countries. About 181.81 kg. of chemicals are used for one tonne of paper. Undoubtedly, water pollution is a major environmental problem of the pulp and paper industry.

Waste streams from integrated paper mills (IPMs) contain large quantities of suspended and dissolved organic and inorganic materials. Suspended solids consist of silt and bark particles originating in the wood room, coating and fillers (i.e. talc, dry calcium carbonate and titanium dioxide) from paper making processes and fibre particles from both pulping and paper making. Approximately 75–90% is readily settleable and the remainder is colloidal. The BOD discharged from the Kraft process paper mill is about 25 kg per tonne of pulp product. Black liquor is not segregated and it ends up in pulp-washing waste water. Thus, the pulp-washing section contributes nearly 80% of the total pollution load.

The dissolved organics originating from raw wood consist of wood sugars, carbohydrates, lignin and related compounds, as well as cellulosic fibre. While some of the organics exert a large BOD, others such as cellulose and lignin are, for the most part, non-biodegradable. Lignin imparts a dark brown colour to process water from chemical pulping.

In a study conducted by the Council of Economic Priorities, it was found that the BOD generated from mechanical wood pulp is 10 kg per tonne, from Kraft pulp, 16 kg per tonne and 22 kg per tonne or more from sulphite pulp. These figures are doubled when the pulp is bleached.

Liquid effluent characteristics from the Indian pulp and paper industry as against the standards is given in Table 4.10.

Only the large capacity pulp and paper mills have any kind of water pollution treatment facilities.

Primary treatment processes employed, use purification apparatus such as catch pits, presses and filters. They can extract between 75% of non-filterable wastes and 25% of the waste water BOD content. The secondary processes employed are the biological

Table 4.10. Liquid effluent standards levels in the pulp and paper industry

Characteristics	Present status		Standards
	Small mills	*Large mills*	
Flow	310 m^3/tonne of paper (rayon grade/newsprint) 200 m^3/tonne of paper for pulp and paper	200 m^3/tonne	175
pH	6.5–8.3	6.0–9.0	6.5–8.5
SS (mg/l)	375	100	100
BOD (mg/l)	160	50	30
COD (mg/l)	610	—	—

methods by which up to 95% of the BOD content can be reduced. The tertiary methods employed are chemical processes to extract nitrogen and phosphates, or micro-filtration.

Solid waste pollution

Solid wastes are generated from the following operations:

- raw material handling,
- rejects from screening and centri-cleaners,
- primary and secondary sludge from waste water treatment systems, and
- coal and boiler ash from steam generation,

Solid waste management studies reveal that about 1.5 tonnes of solid waste is generated per tonne of product. Of this, 84% is inorganic and 16% organic in nature. Lime mud (mostly calcium carbonate), to the extent of 0.55 tonnes, is generated for every tonne of paper and is not used for lime recovery due to its high silica content. The present method of disposal creates leaching and run-off problems.

Solid wastes from modern IPMs are toxic, have relatively low pH levels and low dye content. Besides slime, the solid wastes also include paper residue, wood ash, coal cinders (where the factory uses coal as a fuel) and bark waste.

Cement industry

An important aspect in the ongoing expansion of the Indian cement industry is the potential impact on the environment. A cement plant produces noise, gaseous emissions i.e. SO_2 and NO_x, and particulate emissions, all of which must be controlled to reasonable levels to prevent any significant deterioration of the environment. The dominating environmental problem of the cement industry, however, is the emission of dust through stacks and vents and from fugitive sources. Dust sources are of two types:

- process related sources, such as mills, kilns, coolers, wherein the flow of air/gas, inherent in the system, entrains the dust handled in the section,

- fugitive dust sources, such as conveyor transfer points, leaking joints, open material stock pile, discharge from hoppers, wherein the generated dust becomes airborne near the source itself.

The cement plant's impact on the environment is local and is generally limited to a radius of a maximum of 10 km from its location. The pollutant mass flow from the tall stacks of cement plants is generally too small and the cement plants are too scattered for long-range transport of their pollutants. Appropriate legislations, therefore, aim at having the emissions controlled to levels that meet occupational health requirements within the plant, and are compatible with the use and nature of the surrounding lands.

Considering the contribution of air pollution by the cement industry, the CPCB in close consultation with the SPCBs and the Association of Cement Industry evolved emission standards (MINAS) for cement plants of different capacities. These are given in Table 4.11.

Table 4.11. Emission standards for cement industry

	Total dust not to exceed (mg/Nm^{3}[b])	
Plant production capacity	*Protected area*	*Other area*
200 TPD[a] or less (All sections)	250	150
Greater than 200 TPD (All sections)	250	400

[a]tonnes per day [b]milligrams per normal cubic metres

Notes

1/ The above concentration of particulate matter should not exceed the limits mentioned above The standards are applicable to the emissions from the rotary kiln, raw mill, coal mill, clinker cooler, cement mill, and packing section

2/ Where continuous monitoring integrators are provided on dust emission lines, the integrated average values over a period, to be fixed by the Central and State Boards but not exceeding 72 hours, shall be considered instead of momentary dust emission value conformity to standards

The concentration of particulate matter as shown in Table 4.9 should not exceed the above mentioned limits. The standards are applicable to the emissions from the rotary kiln, raw mill, coal mill, clinker cooler, cement mill and packing section. The emission from the kiln is the most intense compared to other sections which can be minimized only by installation of ESP or by a modern glass-bag house.

The cement industry had incurred a cumulative expenditure on pollution control Rs 2.6 billion till March 1992. Table 4.12 gives typical dust generation from various sources

With the tightening of environmental standards and enforcement by the Government since the early 1980s and the substantial modernization of the industry during this period, most cement plants have installed environmental protection equipment and have, therefore, greatly improved their prospects of meeting the Indian environmental standards which are laid down. According to the findings of a task force

Table 4.12. Dust generation in different cement process plants

Cement process plants	Temp (°C)	Moisture content	Gas flow Nm³/kg clinker	Dew point (°C)	Dust concentration (g/Nm³)	Particle size distance**	Dust generation (mg/Nm³)
Raw mill (using separator collector)	60–65	—	—	—	100–100	60–90	—
Dry Process kilns	270–380	5–8	2 3–3.4	40–45	40–102	60–95	14–27
Wet Process kilns	140–180	18–20	4 5–5 7	70–75	18–42	40–80	13–24
Lepo kilns	94–112	—	3.7–4 0	—	7–8	56–58	about 3
Clinker cooler	100–250	—	—	—	7–14	80*	—
Cement mill	—	—	40–60	80–500	30–70	—	80–122
Coal mill	45–50	—	—	20–25	30–50	90	—
Packing plant	ambient	—	—	—	26–45	65	—

*more than 60 microns **% less than 5 microns

appointed by the CPCB in 1988, out of 94 cement plants, 58 had adequate pollution control equipment for their kilns and were maintaining the exhaust dust content within the Indian emission standards. A further 25 units have already submitted time-bound programmes to meet pollution control standards. Of the remaining 11 plants, 5 have been closed down due to economic reasons, and 2 have been closed through legal actions based on environmental violations. For the remaining four plants that had not submitted time-bound programmes for pollution control, efforts were being made by the respective SPCBs under the direction of the CPCB to force these units to implement required actions. Since 1984, the Government of India has also made environmental clearance a condition of project approval in many industries including cement, thereby ensuring that new capacity meets the country's environmental protection standards.

Fertilizer industry

The major gaseous and liquid pollutants from fertilizer manufacturing plants are listed in Table 4.13 below:

Table 4.13. Gaseous pollutants from various fertilizer plants

Plant	Gaseous pollutants	Liquid pollutants
Ammonia	SO_2	Ammoniacal nitrate
Nitric acid	NO_x	Ammoniacal nitrate
Sulphuric acid	SO_2	
Phosphoric acid	SPM[a], fluorine	Fluorides
Urea	SPM	Ammoniacal nitrate, urea, nitrogen
SSP[b]/TSP[c]	SPM, fluorine	Fluorides, phosphates
N, P/N, P, K[d]	NO_x, SPM, fluorine	Fluorides, phosphates

[a] suspended particulate matter [b] single superphosphate [c] triple super phosphate [d] nitrogen, phosphorous, potassium

Air pollution control measures

Oxides of sulphur: Sulphuric acid plants are the main source of SO_2. The SO_2 emission is inversely proportional to the conversion (SO_2 to SO_3) efficiency, although in recent times, higher conversion efficiencies (about 99.5%) have been achieved. In the initial start-up or start-up after a shut down of more than 4 hours, when catalyst beds are cold, the temperature is inadequate, resulting in higher emissions of SO_2 during start-up. Sulphuric acid plants are, therefore, using either a start-up heater to increase the catalyst bed temperature to the required level, or a start-up scrubber (which is a packed tower using caustic soda to absorb the SO_2). In the case of start-up scrubbing, $Na_2SO_3/NaHSO_3$ is formed depending on the plant of the scrubbing solution.

Particulate emissions

The various sources of particulate emissions are urea plants and complex fertilizer plants.

- Urea plants: Most of the urea plants use wet scrubbers for particulate removal. In this method, dust-laden air in the prilling tower is made to pass through the annular dust and this air is drawn from the dust by a ring of liquid jets.
- Complex fertilizer plants: Normally, fabric filters are used for rock grinding and wet scrubbers like venturi scrubbers for granulation (i.e. drying of slurry in an equipment called the *Spherodizer*). The hot gases are sucked out by an exhaust and enter the venturi scrubber whose essential feature is the presence of a constricted cross-section or *throat*, through which the gas is forced to flow at high velocity. Bag houses are commonly used for dust control in grinding of rock phosphate. The dust concentration to the inlet of the bag house is normally in the range of 20–30 g/Nm^3 which is brought down to less than 150 mg/Nm^3.

Oxides of nitrogen

Nitric acid plants and nitrophosphate (NP) plants are the major sources of NO_x emissions.

- Nitric acid plants: The catalytic reduction (non-selective and selective) method is used to control NO_x. In the catalytic reduction (non-selective) method, the tail gas from the absorber is mixed with a fuel gas like natural gas and the mixture is passed over a catalyst [platinum, vanadium, iron oxide or titanium - based] bed. This converts NO_2 to NO, rendering the exit gas colourless. In the catalytic reaction (selective) method, selective reduction of NO_x in the tail gas is done with a slight excess of stoichiometric quantities of ammonia over a mixed catalyst.
- NP plants: The emission of NO_x takes place during the treatment of rock phosphate with nitric acid. The NO_x emissions can be minimized by maintaining proper temperature in the acidulation reactor.

Fluorine emissions

Phosphoric acid plants and SSP plants are the major source of fluorine emissions. In several plants, fluorine is recovered as hydrofluorosilicic acid. The fluorine emissions are controlled by scrubbing these gases in either venturi scrubbers, packed towers, cross-flow scrubbers or spray chambers.

Pollution standards applicable to the fertilizer industry are given in Tables 4.14 and 4.15.

Table 4.14. Pollution standards for nitrogenous fertilizers plants

	Concentration in the effluents not to exceed mg/l (except for pH)	
Parameters	*Plants commissioned after January 1, 1982*	*Plants commissioned prior to January 1, 1982 (b)*
Liquid effluents		
Straight nitrogenous fertilizers, excluding the calcium ammonium nitrate and ammonium nitrate fertilizer		
• pH	6.5–8.0	6.5–8.0
• Ammoniacal nitrogen	50.0	75.0
• Total Kjeldahl nitrogen	100.0	150.0
• Free ammoniacal nitrogen	4.0	4.0
• Nitrate nitrogen	10.0	10.0
• Cyanide as CN	0.2	0.2
• Vanadium as V	0.2	0.2
• Arsenic as As	0.2	0.2
• Suspended solids	100.0	100.0
• Oil and grease	10.0	10.0
• Hexavalent*		
• Chromium as Cr.	0.1	01.0
• Total chromium as Cr.*	2.0	2.0
Straight nitrogenous fertilizers including calcium ammonium and ammonium nitrate fertilizers	Concentration of all parameters in the effluents remains the same except nitrate nitrogen. Concentration of nitrate nitrogen in the effluent not to exceed 20 mg/l.	
Suspended particulate emissions		
Parameter	Prilling tower commissioned after January 1, 1982	Prilling tower commissioned prior to January 1, 1982
Urea (particulate matter emissions)	50 mg per normal cubic metre (or)	150 mg per normal cubic metre (or)
	0.5 kg/t of urea	2 kg/t of urea

*To be compiled at the outlet of chromate removal unit

Source. Central Pollution Control Board, New Delhi

Table 4.15. Pollution standards for phosphatic fertilizer plants

Parameters	Concentration in the effluents not to exceed milligram (mg) per litre (except for pH)	
Liquid effluents		
Straight phosphate fertilizer		
• pH		7.0–9.0
• Phosphate as P		5.0
• Oil and grease		10.0
• Suspended solids		100.0
• Fluoride as F*		10.0
• Hexavalent chromium as Cr**		0.1
• Total chromium as Cr**		2.0
Complex fertilizers excluding calcium ammonium nitrate, ammonium nitrate and ammonium nitrophosphate fertilizers	**Plants commissioned January 1, 1982 onwards (a)**	**Plants commissioned prior to January 1, 1982 (b)**
• pH	6.5–8.0	6.5–8.0
• Ammoniacal nitrogen	50.0	75.0
• Free ammoniacal nitrogen	4.0	4.0
• Total Kjeldahl nitrogen	100.0	150.0
• Nitrate nitrogen	10.0	10.0
• Cyanide as CN	0.2	0.2
• Vanadium as V	0.2	0.2
• Arsenic as As	0.2	0.2
• Phosphate as P	5.0	5.0
• Oil and grease	10.0	10.0
• Suspended solids	100.0	100.0
• Fluoride as F*	10.0	10.0
• Hexavalent chromium as Cr**	0.1	0.1
• Total chromium as Cr**	2.0	2.0
Complex fertilizers including calcium ammonium nitrate, ammonium nitrate and ammonium nitrophosphate fertilizers	Concentration of all parameters in the effluent remains the same except nitrate nitrogen. Concentration of nitrate nitrogen in the effluent not to exceed 20 mg/l.	
Gaseous emissions		
Phosphatic fertilizers (fluoride and particulate matter emission)	Phosphoric acid manufacturing unit. Granulation, mixing and grinding of rock phosphate.	25 mg per normal cubic metre as total fluoride 150 mg per normal cubic metre of particulate matter
Nitric acid (emission of oxides of nitrogen)	Emission of oxides of nitrogen	3 kg of oxides of nitrogen per tonne of weak acid (before concentration) produced.
Sulphuric acid (emission of sulphur dioxide and acid mist)	Sulphur dioxide emissions	4 kg/t of concentrated (one hundred per cent acid produced, 50 mg/normal cubic metre

*To be complied with at the outlet of fluoride removal unit. If the recipient system so demands, fluoride as F shall be limited to 1.5 mg/l

**To be complied with at the outlet of chromate removal unit

Source: CPCB, New Delhi

Status of pollution control in the fertilizer industry

Table 4.16 gives the status of compliance with prescribed standards for the fertilizer industry.

Table 4.16. Industries complying with the standards

Category	Straight nitrogenous fertilizer	Complex fertilizer	Single super-phosphate	Total
No. of industries	28	16	62*	106
No. of units complying with MINAS and emission standards	10	08(1**)	15(3**)	33(4**)
No. of units complying with MINAS	12	11	19	42
No. of units complying with emission standards	11	09(1**)	18(5**)	38(6**)
No. of units for which information is not available	07	01	34	42
No. of units closed down	—	—	—	—
No of units (large) which *are under installation*	03	—	—	03

*SSI units which are not sending any information are excluded
**Units not complying with fluoride emission standards
Source CPCB, New Delhi (1993)

Aluminium industry

Environmental hazards due to the aluminium industry basically originate from the mining of bauxite i.e. the principal raw material produced through open-pit mining in India. Open-pit mining generates a large amount of dust. Moreover, this ore is subjected to grinding and granulometric sorting which again generates dust. Fresh bauxite is chemically very active and is easily attacked by atmospheric oxygen, moisture and microorganisms. During the rainy season, the water which drains over the ore turns acidic and seeps into the water table. Water runoff from the mines thus pollutes both the ground water table as well as the surface water.

At the alumina refining stage, the environmental problems are created by disposal of red mud, which is a waste product of the process of refining alumina from bauxite, pollutants like coal dust from steam generators, alumina dust from calcining and stack emissions of SO_2 from the refinery and other miscellaneous wastes. Red mud consists of oxides of aluminium, iron, titanium and silicon as major constituents and oxides of vanadium, gallium, calcium, magnesium, etc. as minor constituents. The ratio between these and the end product is 1:1. The residue from aluminium-rich liquor is dumped into tanks which generate dust and pollute ground water through seepage, etc. When the ponds get filled up, new disposal sites are selected and this land cannot be put to any agricultural use.

The major pollutants released during smelting are gaseous and particulate fluoride emissions. About 780 m^3 gases are produced per tonne of alumina from cryolite, aluminium fluoride, calcium fluoride and sodium fluoride used in the electrolytic process.

A list of the type of pollution and pollutants in the aluminium industry is provided in Table 4.17. Energy-related pollution would result more from the aluminium industry's contribution to electricity demands.

Table 4.17. Type of pollution and pollutants in a typical aluminium plant

Type of pollution	*Material produced*
Gaseous emissions	Carbon monoxide, carbon dioxide, hydrogen fluoride, sulphur dioxide, carbon disulphide, silicon tetrafluoride, carbon tetrafluoride, hexa fluoroethane, water vapour.
Solid emissions	Alumina, cryolite, aluminium fluoride, calcium fluoride, carbon, iron oxide.
Liquid effluent	Fluorine compounds, hydrocarbons entrained water
Smelter wastes	Spent potlinings, anode butts from prebaked pots, dust from gas cleaning, sludge from cleaning and scrubbing water, material from pot skimming, spills.
Paste preparation emissions and wastes	Coke dust, coal dust fines, hydrocarbon fumes.
Anode baking emissions and wastes	Hydrocarbons, fluorides, sulphur.
Cast house emissions and waste	Fluxing fumes (primarily aluminium and chloride) trace fluorine, sulphur dioxide.
Ancillary operations emissions and wastes	Dust from bulk material handling, demolition of old pots and cleaning of prebaked anode butts to recover carbon

Source. Towards a strategy for aluminium in India, R S Ganapathy and G Padmanabhan, Department of Science & Technology, New Delhi

Cotton textiles industry

The pattern of production of cloth in the textile industry shows a very wide variation with regard to quantity, types of fabrics produced, and their quality. It also includes the production of cotton blended with man-made fibres like polyester, nylon and rayon. Obviously, the environmental impacts will also vary with the processes. The textile industry has developed in the small sector wherein a vast number of small textile processing units are scattered all over the country. Generally, these units do not have any mechanical equipment. Being in the unorganized sector, these units do not install any pollution control equipment and are thus responsible for high levels of pollution in certain parts of India. A large number of such units are located in Ahmedabad, Surat and Jetpur in Gujarat, and in Pali and Balora in Rajasthan.

Solid wastes are generated in the cotton textile mills in every section from the preparation of raw cotton, spinning and weaving sections, the various wet processes and the finishing of fabrics. The boiler house burning coal, produces a large quantum of cinder and fly ash. The chemical and biological treatment plants produce fairly large quantities of sludge. However, in general, solid wastes are not a big problem.

The waste water from the textile industry is generally coloured, high in BOD, COD and suspended solids, highly alkaline and has a fairly high temperature (Table 4.18). Waste water characteristics are highly variable and sometimes contain toxic chemicals and metals. It is estimated that 12–65 litres of water are required for processing one metre of cloth which produces about 20–30 grams of BOD per metre of cloth processed. The volume of waste water generated varies from mill to mill and lies in the range of 35–520 litres per kg of cloth produced with an average figure of 170 litres/kg.

The waste water from an integrated textile mill contains a large variety of organic and inorganic chemicals such as dyes, pigments, and other chemicals used in the different processes such as starch, carboxymethyl cellulose, dextrine, soap, detergents and heavy metals like chromium.

Table 4.18. Composition of the process waste water in textile mills

Unit process	*Composition of the waste water*	*Characteristics*	*Effluent generated*
Sizing	Starch and the softener originating from the washing	High BOD	
Desizing	Starch, glucose, CMC, PVC resigns, fats and waxes	High BOD 35–50% of total CMC and PVA do not exert a high BOD, neutral pH, high total solids	About 1100–1200 cu m /day effluent produced, which is about 30% of the total pollution load from the mill.
Kiering	Caustic soda, waxes, grease, soda ash, soda silicate and cloth pieces	Strongly alkaline, coloured, high BOD cloth pieces (30% of total), high total solids, high temperature	
Bleaching	Hypochlorite, chlorine, caustic soda, hydrogen peroxide (H_2O_2), acids	Alkaline contributes fairly high BOD, high solids	About 220–290 cu m /day effluent produced, contributing 10% of the total pollution load
Mercerizing	Caustic soda	Strongly alkaline, low BOD (less than 1 per cent of total) high sodium content, low solids	Sodium hydroxide is recovered and the water is recycled
Unit Process	Composition of the waste water	Characteristics	Effluent generated
Dyeing	Various dyes, mordant and reducing agents	Strongly coloured high BOD and COD	400–500 cu m/day
Printing	Various colours, starch gums, china clay, mordants, acids metallic salts	Highly coloured, fairly oily, high BOD and oil	
Finishing	Traces of starch tallow, common salt, sodium sulphate (Na_2SO_4), etc	Slightly alkaline low BOD	

Fly dust, fibre and seed dust are the main sources of air pollution in the spinning process. Textile mills also generate a lot of fly ash and dust affecting the environment as well as the health of the workers. Safety or protective equipments, like filter mask to guard the damage due to fly ash and dust, are not used in the mills.

Soda ash industry

Soda ash industry generates a large quantity of solid, liquid and gaseous effluents. All the investigations and studies have confirmed that the effluent from soda ash industries is non-toxic in nature. It does not contain any organic matter such as COD or BOD. The constituents of effluents are compatible with the sea body system. Gaseous emissions from this industry consist mainly of carbon dioxide emitted from the top of kilns at a high elevation.

The following norms have been stipulated by CPCB in keeping with the minimal national standards (Table 4.19).

Table 4.19. Minimal national standards

Paramater	*Quantitative limit*
Total suspended solids	Should not exceed 6000 mg/l.
pH	Up to 9.5
Nitrogen as ammonia	15 mg/l
Temperature	45°C

There is some dust emanating from the solid-handling section of the Solvay process but no separate standard has been laid down. The tolerance limit for particulate matter in atmospheric emissions is 250 mg/Nm^3.

Table 4.20 lists the tolerance limits for other gases emitted in the soda ash industry:

Table 4.20. Emission of gases

Paramater	*Source*	*Tolerance limit*
Dust particle	TPS and foundry stack	150 mg/m^3
Dust particle	Stack attached to H_2S furnace	100 mg/m^3
SO_2	TPS and foundry stack	100 ppm
H_2O	Stack attached to H_2S furnace	25 ppm

Caustic soda industry

Gaseous pollution. Emissions from the diaphragm and mercury cell plants include chlorine and hydrogen. Gaseous chlorine is present in the blow gas from liquefaction, from vents in tank cars and tank containers during loading and unloading, and in storage tanks and process transfer tanks. Other emissions include mercury vapour from mercury cathode cells and chlorine from compressor seals, header seals, and the air-blowing of depleted brine in mercury cell plant. Gaseous emission standards prescribed by CPCB are as follows in Table 4.21.

Table 4.21. Gaseous emission standards

Source	*Emission limit*
Mercury from hydrogen gas holder stack	0 2 mg/Nm^3
Chlorine from hypo towers	15 mg/Nm^3
Hydrochloric acid vapour and mist from HCl plant	35 mg/Nm^3

Solid waste. The specific consumption of asbestos per tonne of caustic soda in the diaphragm cell process has been found to be about 48 kg which is extremely high compared to the world standard of about 15 Kg. The CPCB has suggested the permissible emission of asbestos to be around 0.3 kg/t of caustic soda in the diaphragm cell using metallic anodes and modified diaphragms.

Liquid pollutants. The emission of mercury in the environment is the major problem with the mercury cell process. Most of the Indian mercury cell process plants have been incorporating pollution control measures, and many of them have reduced mercury consumption from 350 gm/t of caustic soda to about 90 gm/t. Lower consumption of mercury means less mercury loss from the process. The unit having the lowest specific consumption of mercury per tonne of caustic soda is found to be recirculating the largest amount (about 40%) of mercury-bearing waste brine. The level of specific consumption of mercury in advanced countries has been brought down to less than 20 gm/t of caustic soda. Average mercury discharge by Indian caustic soda units is observed to be more than 100 gm/t of caustic soda produced.

Mercury in effluent. Indian chlor-caustic units have already achieved the standard stipulated concentration of mercury in liquid effluents but it is being revised by the CPCB to reduce it further (Table 4.22).

Table 4.22. Mercury in liquid effluent

Norm status	*Flow of effluent* *(m^3/t)*	*Mercury concentration* *(mg/l)*
Achieved	10	0.010
After revision	2	0.005

Mercury in hydrogen gas. CPCB recommends the quantity of mercury discharge with hydrogen gas as follows (Table 4.23):

Table 4.23. Mercury discharge with hydrogen gas

Pollutant	*From the decomposer*	*After treatment*
Quantity of Mercury (gm/m^3)	800	0.01 (Stipulated)

Petrochemical industry

The petrochemical industry encompasses a wide spectrum of synthetic chemicals. Numerous processes including polymerization, hydrogenation, halogenation, epoxidation, alkylation, nitration, hydrocarboxylation, sulphonation, distillation, isomerization and crystallization are used by the industry. Not surprisingly, there is considerable potential for the production and release of pollutants. Many of the products and intermediates are toxic. The type and nature of various pollutants is presented in Table 4.24.

The current national standards for environmental protection are generated by the MINAS for the petrochemical Industry (1988), the National Ambient Air Quality Standards, the Manufacture/Storage/Import of Hazardous Chemicals Rules (1989) and the Hazardous Wastes (Management and Handling) Rules (1989).

MINAS are for liquid effluents. Two main aspects are taken into consideration for the development of standards for waste water discharges. One relates to the adverse effects on health and the environment and the other to the achievability of limits of pollutants by incorporation of appropriate pollution control measures.

The latter approach aims at the use of best available and economically feasible technology. Economically feasible technology assures that the cost of pollution control measures will remain within the affordability of industrial units. The MINAS are techno-economic standards, developed on the above principles by the CPCB. These standards are

Table 4.24. Pollutants from the petrochemical industry

Product	*Process*	*Pollutants*
Ethyl benzene	Alkylation	Tar, HCl, caustic, oil, HCN, unreacted soluble hydrocarbons
Butadiene	From n-butane and butvlene	Residue gas, tars, oils, soluble hydrocarbons
Stvrene	From ethyl benzene	Spent catalyst, aromatic hydrocarbons including styrene, ethyl benzene, toluene and tars Heavy ends.
2-Ethyl hexanol	Hydrocarboxilation (oxoprocess)	Soluble hydrocarbons, aldehydes
Acrylonitrile	Hydro-cyanation	Cyanides, organic and inorganic compounds
Benzenexylene	Isomerization	Hydrocarbons aliphatic, aromatic and derivative tars
Ethylene oxide/ethylene glycol	Oxidation	$CaCl_2$, spent lime, hydro carbon ethylene polymers, ethylene oxide, glycols
Aldehydes, alcohols and acids, organic acids	From hydrocarbons	Acetone, formaldehyde, acetal alcohols, methanol, higher alcohols and organic acids
Acids and anhydrides	Aromatic oxidation	Acids, aromatics and acids
Phenol/acetone		Formic acid, hydrocarbons

uniform throughout the country and those for the petrochemical industry are provided in Table 4.25.

Table 4.25. MINAS for petrochemical industries (basic and intermediate products)

Parameter	*Limits not to be exceeded*
pH	6.5–8.5
BOD 520°C, mg/l[1]	50.0
COD, mg/l	250.0
Phenol, mg/l[2]	5.0
Sulphide as S, mg/l	2.0
Cyanide as CN, mg/l	0.2
Flouride as F, mg/l[3]	15.0
Hexavalent chromium as Cr, mg/l[4]	0.1
Total chromium as Cr, mg/l	2.0
Total suspended solids, mg/l	100.0

Notes.

1/ State Board may prescribe a lower BOD value (say 30 mg/l) if the recipient system so demands

2/ The limit for phenol shall conform at the outlet of effluent treatment of phenol cumene plant. However, at the final disposal point, the limit shall be less than 1 mg/l

3/ The limit for fluoride shall conform at the outlet of fluoride removal unit. However, at the disposal point, concentration shall be lower than 5 mg/l

4/ The limits for total and hexavalent chromium shall conform at the outlet of the chromate removal unit. This implies that in the final treated effluent, total and hexavalent chromium shall be lower than that prescribed

Source Minimal National Standards, Petrochemical Industry, Central Pollution Control Board

A study was conducted on four major petrochemical industries [Indian Petroleum Limited (IPCL), National Organic Chemical Industry Limited (NOCIL), Gujarat State Fertilizer Corporation (GSFC) and Herdillia Ltd] by the CPCB. These industries had installed ETPs to comply with the relevant standards prescribed by the SPCBs. The performance study revealed that the industries generally conform to the standards.

Safety in petrochemical industries

At present most of the petrochemical plants in India are surrounded by populated areas. Such plants pose a threat to the people within and outside the plant premises, and the environment in general.

Petrochemical production involves raw materials, intermediate products and final products which are reactive, explosive and toxic. Typical examples are hydrogen cyanide, ethylene oxide, light hydrocarbons, etc. Special safety measures are necessary to minimize such hazards.

Environmental implications of energy use in transport

The environmental implications of energy use in the transport sector are largely felt on the atmosphere due to the exhaust emissions from various vehicles. The exhaust from motorized vehicles comprises CO_2, CO, HC, NO_x, SO_2, Pb, and TSP. These pollution problems are further compounded in cities where atmospheric conditions are stable and there is no vertical mixing (or motion) of air.

The control of air pollution in existing vehicles can be ensured only by the enforcement of the Central Motor Vehicles Rules, 1989 which have introduced nationwide emission standards for both petrol and diesel vehicles. The rules require that the vehicles meet the TSP, smoke and CO emission standards set and every new vehicle manufactured must meet the prescribed standard. Future mass emission norms which would come into effect from 1 April 1996, have been issued for petrol and diesel vehicles under the Central Motor Vehicles Rules, by the Ministry of Surface Transport. The norms include emission standards for type approval and conformity of production tests for vehicles in the manufacturing stage. The various State Transport Authorities have been asked to take suitable steps for implementation of these norms. However, the rules do not cover hydrocarbons (HCs) which are recognized as major air pollutants which cause serious health hazards.

Air quality measurements carried out in several cities provide data on the ambient air quality, but not much data are available about pollutants generated from vehicles. Studies of the CPCB indicate that vehicular activities contribute to about 70% of the total NO_x emissions while their impact in the region is about 98% of the total. The impact of vehicular pollutants is comparatively higher as these are emitted at ground level.

Over the years, different organizations have estimated vehicular pollution loads in urban areas. A study by CPCB in 1991 showed that it is highest in Delhi, followed by Bombay. Among the pollutants, CO emission was maximum and ambient CO and NO_x levels had crossed the prescribed standards. An estimation of carbon dioxide emitted by the road transportation sector in the metropolitan cities in 1990 shows that Delhi contributed over 700 000 tonnes while Bombay contributed approximately 500 000 tonnes. Motor vehicles in India contribute about 0.52% of the total CO_2 emissions from road transport all over the world.

Vehicles plying in the major metropolitan cities of India are estimated to account for about 70% of CO, 50% of HC, 30–40% of NOx, 30% of TSP and 10% of SO_2 pollution in these cities.

Data on emission factors are normally expressed in grams of pollutant per litre of fuel used by various types of vehicles under the typical driving cycle[3]. Emission factors for six major pollutants—CO, HC, NO_x, SO_2, Pb and TSP, under the typical Indian driving cycle are given in Table 4.26.

Table 4.26. Emission factors for the EDB[b] structure in LEAP[a]

	Unit	*CO*	*HC*	*Pb*	*NO_x*	*SO_x*	*TSP*
Car/jeep/taxi	g/l	262.00	38.90	0.20	17.10	0.58	—
2-wheeler	g/l	369.00	230.00	0.20	—	0.58	—
3-wheeler	g/l	249.00	155.00	0.20	—	0.58	—
Bus/truck	g/l	18.80	4.30	—	35.60	6.20	1.18
LCV	g/l	2.36	0.91	—	4.45	6.20	0.15
Diesel locomotive	g/kg	n.a	4.25[*]	—	35.00[a]	n.a	n.a
Steam locomotive	g/kg	n.a	n.a	—	n.a	n.a	n.a

[*] US Environmental Protection Agency (1985) AP–42, Vol II

[a] long-range Energy Alternatives Planning System, Stockholm Environment Institute, Boston

[b] environmental database

Source IIP (1985) *State-of-Art-Report on Vehicle Emissions*, Indian Institute of Petroleum, Dehra Dun

The daily pollution load generated due to automobiles in the metropolitan cities, estimated by the CPCB is shown in Table 4.27.

Table 4.27. Daily pollution due to automobiles

	Vehicular pollution load (tonnes per day)				
Name of the city	*TSP*	*SO_2*	*NOx*	*HC*	*CO*
Delhi	8.6	7.5	105.4	208.0	542.5
Bombay	4.7	3.4	59.0	90.2	391.6
Bangalore	2.2	1.5	21.9	65.4	162.8
Calcutta	2.7	3.0	45.6	36.6	156.9
Ahmedabad	2.5	2.4	33.3	56.5	149.3
Pune	2.0	1.1	13.5	61.0	135.2
Madras	2.0	1.7	23.5	42.1	119.4
Hyderabad	1.6	1.3	14.0	46.9	105.1
Jaipur	1.0	1.0	12.7	17.5	42.7
Kanpur	0.9	0.9	11.1	18.5	40.4
Lucknow	0.9	0.8	8.1	18.8	41.0
Nagpur	0.5	0.3	4.2	13.6	29.2

Source. CPCB, Control of Urban Pollution Series. CUPS/17/1988-89

At present, the quantum of vehicular pollutants emitted is highest in Delhi followed by Bombay, Bangalore, Calcutta and Ahmedabad.

In gasoline and petrol driven car exhausts, tailpipe emissions account for the entire CO, NO_x and lead derivate/emissions. Insofar as HCs are concerned, about 60% is contributed by exhaust emissions while the remainder can be attributed to fuel evaporation from the fuel tank/carburettor and crankcase blowby.

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[3] In India, the driving cycle adopted for measuring the emission factors is termed as a four-cycle mode and consists of idling, acceleration, cruising and deceleration. These driving cycles are simulated by running the vehicles on a chassis dynamometer in the laboratory of Indian Institute of Petroleum, Dehra Dun

Two-wheelers which are generally fitted with two-stroke engines are getting increasingly popular because of greater fuel economy, better specific power, lower operational and maintenance costs and lower production costs. The inherent weakness of the existing design of 2-stroke engines (also fitted in three-wheelers) in India is that 25–40% of the fuel supplied is discharged without being combusted.

Diesel vehicular exhaust pollution is in the form of particulate matter (carbon and soot which gives diesel smoke a jetblack colour), aldehydes (which impart obnoxious odour), carbon monoxide, unburned hydrocarbons and oxides of nitrogen.

A study by CPCB on the ambient noise levels in some metropolitan cities shows that the noise levels in most of the cities exceeds the prescribed standards and that vehicles are the major source of noise. The study on the effect of auto pollution on the health of Delhi traffic policemen by the Central Road Research Institute (CRRI) showed excessive CO in their breath and most of them complained of eye irritation, respiratory problems and discomfort.

The present trend of increasing private passenger transport (Delhi adds one motor vehicle every 5 minutes and Bangalore, every 7 minutes) and the increase in travel demand, indicates further air pollution, congestion and accompanying health problems.

Environmental impacts of household energy use

The main energy forms used in the middle and upper echelons of urban households are LPG, and to some extent, kerosene and electricity. In this sector, the fuel use pattern in the lower tiers of urban households and rural households is of concern, as their energy consumption patterns are similar and exhibit a significant biomass dependence. Most of the discussion in this section would focus on rural energy use but the same arguments could be extended to the biomass energy use in urban households.

There are essentially two major environmental impacts due to biomass energy use in the households sector: the impact on the natural resource base and the impact on quality of life.

Effect on natural resource base

India has, and still is, suffering rapid forest denudation. Analysis of satellite imagery of forest cover data, shows that from 1972–75 to 1980–82, the area of closed and open forest cover declined from 55.52–46.35 Mha (or 16.9–14.1% of the total land area), a loss of about 1.2 Mha per year. In the latter period, the forest cover was only 0.05 ha per person, among the lowest in the world. Closed forests (defined as a canopy cover of at least 40%) dropped from 46.42–36.02 Mha, while the area of open and degraded forests rose from

8.77–10.06 Mha. The balance consists of mangrove forests, which fell from 0.33–0.26 Mha (Centre for Science and Environment 1985). These losses are about seven times greater than previous official estimates for a *forest land*, much of which has no trees on it.

During the '70s, it was commonly assumed that rural energy use was one of the prime factors for deforestation in most developing countries. The focus, of course, was also on the scarcity of fuel on account of deforestation. However, as more and more studies were conducted, the assumption on the correlation between fuel use and deforestation has weakened. For instance, the National Council of Applied Economic Research (NCAER) survey showed that nearly 56% of the domestic energy was supplied by fuelwood but over 75% of this was in the form of twigs and branches and further, about 57% of it was collected at a *zero private cost* (NCAER 1985). Furthermore, the survey indicated that the felling of trees for fuelwood was an uncommon practice. On the other hand, there is also evidence of practice of fuelwood extraction (such as lopping of young trees which destroys the middle stock), exacerbating the degradation of biomass resource base where it has already occurred.

However, there is little dispute regarding the fast deteriorating biomass resource base and its adverse impact on the rural lifestyles. Combined with the inability of the people to shift to commercial fuels like kerosene on account of low purchasing power and limited availability, the rural people are facing what many have termed the *other fuel crisis growing out of this eroding biomass resource base.*

Several causes can be identified as having contributed to resource degradation:

- Since the time of the British rule in India, commercial interest has been one of the prime reasons for degradation. To begin with, it was resource outflow to the European countries but the pattern continued even after independence with a lot of thrust having been given to industrial development.
- In the past few decades, demand for agricultural land has become an important factor leading to forest degradation. In the developing countries, 60% of deforestation is attributed to the expansion of agriculture (World Bank 1992). Growing demand for food due to rapidly increasing population has forced encroachment, mostly illegal, on the forests.
- Forest denudation also takes place to some extent due to a variety of other factors like mining, construction of mega-projects, etc.

Where forest depletion has already taken place, fuelwood demand may also be contributing to further degradation. A case in point is the fuelwood headloads: rural people carry fuelwood headloads to the nearby towns to sell, and in the process create a fuelwood market; and once this becomes a regular activity as a reliable source of income, there is a tendency to accelerate the process of degradation in the rural areas surrounding the towns. Nearly a third of the total fuelwood is estimated to be used in urban areas currently.

Table 4.28 demonstrates the sharp reduction in the areas of closed forest within a 100 km radius of nine principal cities in India.

Table 4.28. Decrease in closed forest cover around major cities

	Forest cover (km²)		
City	*1972–75*	*1980–82*	*Decrease (%)*
Delhi	254	101	60
Jaipur	1534	786	49
Madras	918	568	38
Hyderabad	40	26	35
Nagpur	3116	2051	34
Bangalore	3853	2762	28
Calcutta	55	41	25
Coimbatore	5525	4700	15

Source Bowonder *et al* 1985

In macro terms also, the fact that the present consumption level is at 250 Mt as against a sustainable yield of only 85 Mt indicates that the difference is being met from either *unrecorded* or *illegal* sources which may be contributing heavily to the process of degradation.

Effects on quality of life

One of the important manifestations of a deteriorating fuel supply situation, is the increased time and travelling distance for women and children who collect the fuelwood. In most rural areas, especially in hilly regions, women usually participate in both economic and non-economic activities, and increased collection times have a high opportunity cost, though it may not be easy to quantify it. However, the increased burden will have a deleterious effect on the health of women, the education of children, general well-being of the family, etc. Table 4.29 illustrates this problem in different parts of the country.

Table 4.29. Time spent and distance travelled by women

Place	*Time spent*	*Distance travelled*
Chamoli (Hills)		
Dwing	5 hrs per day	> 5 km
Pakhi	4 hrs per day	> 3 km
Gujarat (Plains)		
Forested	once in 4 days	—
Depleted	once in 2 days	4–5 km
Severely depleted	4–5 hrs a day	—
Madhya Pradesh (Plains)	three times a week	5 km
Kumaon (Hills)	three times a week	5–7 km
Karnataka (Plains)	three times a week	5 4 km/trip
Garhwal (Hills)	5 hrs per day	10 km

Burning of biomass fuels in inefficient cook-stoves leads to high levels of indoor air pollution, causing a variety of eye and lung diseases. Though in rural areas, a large portion of time is spent outdoors, the indoor environment in these villages could be so polluted that they dominate the exposures of individuals who work in these environments. Pollutant concentrations vary spatially and temporally and people's activity patterns affect the exposure received. Total exposure assessment, at least in conceptual form, is comprehensive in nature and takes these variations into consideration.

There have not been many field studies of indoor air quality in the rural areas of developing countries. In India, the Indian National Institute of Occupational Health (INIOH) made measurements of TSP, SO_2, and NO_2 concentrations in kitchens where biofuels were being burnt in traditional stoves. They found that TSP levels were much higher than the SO_2 and NO_2 levels (INIOH, 1980) as shown in Table 4.30.

Table 4.30. Air quality measurements in kitchens where various biofuels are in use

Cooking fuel	*TSP (mg/m^3)*	*SO_2 (mg/m^3)*	*BaP/TSP (x 10^{-6})*
Cowdung	16.0	0.24	516
Wood	7.2	0.17	176
Wood and cowdung	21.0	0.27	440

Source. Indian National Institute of Occupational Health (INIOH), 1980, Aggarwal *et al.*, 1982

The first field study of exposure was conducted in 1981 in Gujarat. This pilot study measured the exposure of cooks to TSP and the concentration of CO in the cooking area. In addition, the TSP filters were analysed for Benzo(a) pyrene (BaP) (Smith *et al*, 1983). The findings confirmed previous hypothetical calculations that village cooks are, indeed, exposed to high pollutant levels on a regular basis (Smith *et al*, 1981). People invariably cooked indoors and ventilation conditions did vary over the year since during the monsoon season, skylights and openings in the walls and roofs of the kitchens are blocked. Smith *et al*, (1983) found extremely high TSP exposures (peak of 56 mg/m^3) under these conditions. The seasonal variations in exposure then, can be quite substantial.

Biofuel smoke has been established as a risk factor causing acute respiratory infections, the chief cause of infant mortality in the Third World, accounting for nearly 650 000 deaths in India annually (Smith 1993). The incidence of *cor pulmonale*, a heart disease, is found to be high among north-Indian women. Biomass pollution has also been linked to pregnancy-related problems among women. Given that health facilities are still not of a very high quality in rural India, any energy intervention programme designed must consider health improvement as a major objective.

Environmental effects of agricultural operations

The environmental impacts due to agriculture can be divided into two categories: those which are a result of the use of energy, direct or indirect, and those which are non-energy related. The environmental effects which are due to the direct use of energy are essentially emissions associated with the use of diesel for irrigation purposes and for land preparation.

However, the environmental effects of agricultural operations are not necessarily a function of the quantum of energy inputs into the sector. There are several environmental impacts associated indirectly with the use of non-energy inputs. The overuse of fertilizers and pesticides results in deterioration in groundwater quality. It also causes changes in soil texture, salinity and fertility and leads to depletion of soil resources. There is depletion of groundwater as well due to excessive irrigation, and compaction and hard pan formation in the soil due to use of heavy machinery in tillage operations.

However, the use of energy in the agricultural sector has no major environmental impacts *per se*.

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CHAPTER 5

Sectoral growth prospects

Energy demands and hence, growth in India have historically been supply-constrained. However, in the economic reforms process currently underway, these constraints are being removed by paving the way for greater imports of energy. These efforts are apparent in the vigorous pursuit of private capital to enhance public investments in this critical infrastructure sector, reduction of import duties on coal, introduction of the parallel marketing system for petroleum products, advanced stages of negotiations for the setting up of a natural gas pipeline etc.

Energy, however, is an intermediate product used to satisfy various other intermediate and final demands. As such an analysis of energy demand growth prospects, should necessarily be preceded by that of the growth prospects of other economic sectors, including the household sector. For the transport, agriculture and domestic sectors, sectoral growth for the terminal years of the Eighth (1996/97), Ninth (2001/02), Tenth (2006/07) and Eleventh (2011/12) Plan periods, has largely been estimated on the basis of trends. However, in the case of industry, use has been made of industry's own planned growth and governments projections wherever possible.

Industry

Iron and steel

In a liberalized *open economy* framework, the market will not be a constraint for the Indian integrated steel industry, provided its products are internationally competitive in terms of cost and quality. Given Steel Authority of India's(SAIL)long experience as a major producer in the country, the ongoing and proposed modernization programmes for Durgapur Steel Plant Limited (DSP), Rourkela Steel Plant Limited (RSP), Bokaro Steel Limited (BSL), and Indian Iron and Steel Company Limited (IISCO), would provide an ideal base for exploiting the latent potential of Steel Authority of India Limited(SAIL) plants. It has been well established that the modernization and technological upgrading of existing assets is a more economical route for growth than the creation of green-field capacities. One other element in the growth strategy, is the concept of self-reliance to be extended to individual plants. Each is planned to progressively attain the status of a self-sustaining and economically viable unit through optimum choice of product-mix, improvement in capacity utilization, and appropriate investments.

Production planning for integrated steel plants (ISPS)

The crude steel production from the five ISPs of SAIL is targeted at around 19 Mt by the year 2005 (see Table 5.1 below). A little over 1 Mt of saleable pig iron will also be produced. The supporting production of hot metal is planned at 20 Mt.

Table 5.1. Production of crude steel in terminal years ('000 t)

Plant	*1996/97*	*2001/02*	*2004/05*
BSP	4319	4965	5730
DSP	1801	2281	2976
RSP	1850	1900	2800
BSL	4061	4489	5253
Total (4 ISPs)	12031	13635	16759
IISCO	449	2127	2127
SAIL Total	12480	15762	18886

In line with the corporate mission and growth strategy, the saleable steel target of around 17.5 Mt would be dominated by flat products (12.8 Mt); even in the category of non-flat products (4.5 Mt), the thrust would be on specializing in value-added heavy structurals, railway materials and wire rods (Table 5.2). *Semis for sale* would be substantially reduced by the year 2005 as the overall focus would be on increasing the finishing facilities for value addition.

Table 5.2. Growth in production: SAIL (including IISCO) ('000 t)

Parameter	*1991/92*	*1996/97*	*2001/02*	*2004/05*
Hot metal	10596	14428	17177	20200
Crude steel	9870	12479	15762	18886
Saleable steel	7951	10754	14101	17460
non-flats	2269	2532	3245	4468
flats*	4493	6279	8978	12824
Pig iron	790	1655	1281	1007

*including pipes

SAIL's future coking coal needs are planned to be met through indigenous supplies from Coal India Limited, SAIL's captive mines, and imports.

Paper and pulp industry

The demand scenario of paper and paper products, is largely dependent on the following factors:

- economic growth,
- growth of literacy,
- population growth, and
- industrial growth.

Considering that the growth projections for all the above factors show a rise, the demand for paper and paper products is bound to increase as well. To meet this rising demand, it is essential that the paper industry steps up its performance in terms of capacity utilization and modernization.

Assuming a maximum (achievable) capacity utilization of 75% during the Eighth Plan period, it is estimated that the production will be about 31.90 lakh tonnes by the turn of the century (Table 5.3).

Table 5.3. Projected production at 75% capacity utilization

Year	*Rate of growth of paper & pulp industry*	*Capacity creation (Mt)*	*Capacity utilization (Mt)*
1991	5.0	2.8	1.8 (65%)
2000	4.0	4.2	3.2 (75%)

Source Directorate General of Technical Development, 1990

Demand for paper is closely related to many variables like per capita income, industrial production, price of paper, student population and government expenditure on education. However, statistical correlations between demand for paper and all these variables except per capita income do not yield statistically significant results. Demand for many varieties of paper and paper boards, is found to be affected by changes in income and prices. The estimated per capita consumption of paper by category is given in Table 5.4.

Table 5.4. Estimated per capita consumption of paper by category (kg per year)

	1990/91		*1995/96*		*2000/01*	
Category of paper	*High*	*Low*	*High*	*Low*	*High*	*Low*
Writing and Printing paper	1.608	1.064	2.168	1.240	3.504	1.605
Newsprint	0.623	0.426	0.800	0.522	1.204	0.722
Industrial paper	0.584	0.380	0.801	0.472	1.284	0.669
Paperboard	0.700	0.469	0.934	0.567	1.471	0.740
Total	3.515	2.339	4.703	2.801	7.463	3.736

Source. Ahuja S P, 1992. 3 Ahuja S P, 1992

Cement

The Eighth Plan has targeted cement production to go up to 76 Mt by 1996/97, with a capacity of 90 Mt. The slow development of infrastructure like roads, housing and irrigation projects and investment in social sectors like education and health are some of the main reasons cited for the present weak demand. The Government remains the largest single consumer of cement in India, absorbing almost 40% of the total cement produced. Recently, however, the Government has reduced its consumption by nearly 30% and this has created a depressed market for cement in the country. Since demand mainly originates from rural and urban development schemes in housing, irrigation and other construction activities undertaken by the Government, industry has bemoaned the fall in government offtake as a major hurdle in its developmental programme.

The Eighth Plan has made some effort to speed up the implementation of projects in the construction and transport sectors. Studies have pointed out that a one kilometer cement concrete road would lead to a 9 per cent reduction in fuel consumption for vehicles. The export market is another area the industry is exploring. The Eighth Plan makes an export projection of 5 Mt by the end of 1995. This, however, seems ambitious because exports are at present only 358 000 tonnes per year. Besides, as some cement exporters point out, the Government has yet to formulate the right port policy to encourage bulk export of cement.

Fertilizers

The demand estimates for nitrogenous fertilizers have been worked out by various groups using different techniques and approaches which are discussed below:

- *National Informatic Centre (NIC)*: The NIC projections are based on the time series data which have given weightage to the immediate past data rather than the remote past data
- *Project Development India Ltd (PDIL)*: PDIL has considered the past consumption trend for the projections
- *Working Group on nitrogenous fertilizers for Eighth Plan*: The Working Group has adopted computer modelling techniques using the time series data which brings out more prominently the impact of trends in consumption in the immediate past, as well as likely demand on the basis of the need-based approach linking to the target of food grain production
- *Pitam Singh and U S Awasti model (PSUSA)*: The demand projections are based on the past trend for fifteen years also taking into account risk factors (weather conditions and price increase) and advantage factors (more irrigation facilities, good monsoon and additional area coverage for cultivation)

The Fertilizer Association of India (FAI) also estimated the demand for nitrogenous fertilizers. The approach for demand estimation is not available. The demand for nitrogenous fertilizers as estimated by various groups for 1996/97 is given in Table 5.5

As can be seen from Table 5.5, different groups have projected the demand at different levels for the Eighth Plan. However, the variation in the extreme estimates (the lowest and the highest estimates) as given in the table is only 5.21%.

For estimating the demand of nitrogenous fertilizers for future Five Year Plan periods, a compounded annual growth rate of 4.5% has been considered which almost

Table 5.5. Nitrogenous fertilizer demand estimates for 1996/97 by various groups

Group	*Demand (Mt)*
FAI	10.64
WG	11 24
PDIL	11 20
PSUSA	10 67

Source. Pitam Singh and U S Awasti—Fertilizer Industry in India (Part-1), 1992

fits in with the average of the growth rates worked out by various agencies. The estimated demand figures are given in Table 5.6.

Table 5.6. Nitrogenous fertilizer demand estimates

Year	*Demand (Mt)*
1996/97	10 67
2001/02	13 30
2006/07	16.57
2011/12	20 65

The new plants that are heading for commercial production and the existing plants which are embarking on expansion or fuel-change, are either natural gas or naphtha based. The two operating coal-based plants are undergoing feedstock change whereas some of the fuel oil-based plants are planning a change of feedstock to naphtha or natural gas.

Aluminium

The demand for primary aluminium in the years 1994/95, 1999/2000 and 2004/05, as estimated by the Working Group on non-ferrous metals for the Eighth Plan, is given in Table 5.7 which indicates that there is adequate scope for increase in aluminium capacity which would involve modernization/expansion of existing smelters and setting up of new smelters.

Table 5.7. Eighth Plan projections for aluminum ('000 t)

Year	*EC grade*	*CC grade*	*Total*
1994/95	204	372	576
1999/00	269	558	827
2004/05	348	1812	1160

Source Working Group for non-ferrous metals report of sub-group on aluminium, magnesium, etc. for Eighth Plan

The present power requirement for all the aluminium plants in the country is 1426.60 MW. The average specific energy consumption and total energy requirements for aluminium manufacture are given in Table 5.8.

Table 5.8. Energy requirements for the year 1996/97

Production (Mt)	*Energy*	*Electricity*	*Fossil fuels*
0.656	Specific energy	18500 (kWh/t)	15500 (kcal/kg)
	Total energy	12025 (GWh)	1.017 (Mtoe)

Cotton textile industry

The average growth rate during the Seventh Five Year Plan in the textile industry was around 1.8%. The projected production and capacity increases during the Eighth Five Year Plan for the year 1996/97 are expected to be around 3500 million metres in the organized sector and 21 200 million meters in the unorganized sector. GOI gives the demand projections based on a gross domestic products (GDP) growth rate of 6 per cent of the economy during the period 1990–2010. In the Eighth Plan, a provision of about Rs 150 crores has been made for modernization, replacement and upgradation of technologies to realize 15–20% potential for energy conservation.

The energy projection for the sector is expected to improve by 15% from the base year. The projections for specific energy consumption are given in Table 5.9 (based on the Economic and Social Council for Asia and the Pacific, United Nations Development Programme and Government of India Study).

The cotton textile industry at present, with an annual production of about 400 million metres of cloth and approximately 1000 million kg of yarn, is one of the biggest in the country.

Table 5.9. Estimated specific energy consumption in textiles

Year	*Electricity (kWh/Rs of VA)*	*Fossil fuel (kcal/Rs of VA)*
1994	0.306	0.756
2004	0.250	0.618
2009	0.195	0.481

Caustic soda industry

The anticipated capacity utilization in the caustic soda industry for 1996/97 is expected to be around 92% Trends indicate that the production from the membrane and mercury process would be increasing at a cumulative rate of 17.27% and 5.43% respectively and decreasing at a rate of 7.13% from the diaphragm process for the Ninth to Eleventh Five Year Plan periods. The total production of caustic soda is projected to grow at a rate of 8.2%, 7.5%, and 7.0% for the Ninth, Tenth and Eleventh Five Year Plan periods (Table 5.10) and this is apportioned over the various processes taking into account the ratios indicated by the trends given above.

Table 5.10. Projected Production of caustic soda

	Production (tonnes)			
Year	Membrane process	Mercury process	Diaphragm process	Total
1996/97	372 000	11 891 20	38 880	16 000 00
2001/02	816 227	15 326 83	26 605	23 755 16
2006/07	1 616 527	17 825 17	16 394	34 154 39
2011/12	2 918 972	18 907 31	9155	48 183 76

Process-wise thermal and electrical energy demands from 1996–2012 are given in Table 5.11.

Table 5.11. Anticipated thermal and electrical energy demands till 2011/12

Type of process and energy	1996/97	2001/02	2006/07	2011/12
Membrane cell				
Thermal energy (Gcal)	770 040 0	1 689 590 0	3 346 210.0	6 042 272.0
Electrical energy (GWh)	911.5	2000.0	3960.5	7151.5
Mercury cell				
Thermal energy (Gcal)	1 180 000.0	1 530 000.0	1 780 000.0	1 890 000.0
Electrical energy (GWh)	3627.0	4674.7	5436.7	5766.7
Diaphragm cell				
Thermal energy (Gcal)	115 862.0	79 283.0	48 854.0	2728.0
Electrical energy (GWh)	109.0	74 5	45.9	25.6
Total thermal energy (Gcal)	2 065 902.0	3 298 873 0	5 175 064.0	7 935 000.0
Total electrical energy (GWh)	4647.5	6749.2	9443.1	12 943.8

Weighted average specific energy consumption and the total energy demands would be shown in Table 5.12.

Table 5.12. Total energy demand and weighted average specific energy consumption

Year	Weighted average specific energy consumption (kWh/t)	Total energy demand (GWh/year)
1996/97	3388 65	5500
2001/02	3361.80	8165
2006/07	3334 74	11740
2011/12	3309 18	16564

Soda ash industry

Assuming the average specific energy consumption of all the soda ash producing processes at 3000 kWh/t and rate of growth of production in all the soda ash producing units at 8.2%, 7.5%, and 7.0% for the years 2001/02, 2006/07, and 2011/12 respectively, the projected energy requirement for soda ash production in India would be as follows (Table 5.13).

Table 5.13. Anticipated production and energy demand

Year	Production (Mt)	Energy demand (GWh)
1996/97	2.000	6000
2001/02	2.970	8908
2006/07	4 270	12 808
2011/12	6.024	18 069

Major energy conservation measures being adopted in the soda ash manufacturing industrial units are:

- use of improved design of carbonating tower to increase the heating efficiency,
- use of improved heat exchangers for ammonium recovery system,
- use of dry lime in ammonia still for heat recovery, and
- use of steam tube dryer in place of oil fired calciners.

Petrochemical industry

The range of petrochemicals and their usage are wide and diverse. Petrochemicals can be broadly divided into three categories: polymers, intermediates and synthetic fibres. Polymers include polyethylene, polypropylene, polyvinyl chloride, polystyrene and synthetic rubber. Intermediates consist of Acrylonitrile, DMT/PTA, caprolactam, detergent alkylate, methanol and phenol. Synthetic fibres are Nylon Filament Yarn (NFY), PFY, Polyester Staple Fibre (PSF) and Acrylic Staple Fibre (ASF). Based on the growth trend of various products the following are chosen for study:

- High density polyethylene (HDPE)
- Polyvinyl chloride (PVC)
- Dimethyl terephthalic acid (DMT)
- Purified terephthalic Acid (PTA)
- Polyester filament yarn (PFY)

The demand projections for the above products for the Eighth to Eleventh Five Year Plan periods are given in Table 5.14. The corresponding estimated energy demands are given in Table 5.15

High density polyethylene (HDPE)

At present only Polyolefins Industries Ltd (PIL), Bombay is manufacturing HDPE. With the commissioning of Maharasthra Gas Catalytic Cracking (MGCC), Indian Petrochemical Corporation Limited (IPCL) and Reliance Industries (Hazira), the total production of HDPE is expected to reach 293 000 tonnes during 1996/97 (55.72% growth rate). During the Ninth Plan period, the production of HDPE is expected to go up to 762 000 tonnes (21.06% growth rate) For the Tenth and Eleventh Plan periods, the growth rate is assumed to be 8.0% and 7.4% respectively.

Table 5.14. Demand projections for selected petrochemical industries

Product	Eighth Plan Growth rate (%)	Eighth Plan Production ('000 t)	Ninth Plan Growth rate (%)	Ninth Plan Production ('000 t)	Tenth Plan Growth rate (%)	Tenth Plan Production ('000 t)	Eleventh Plan Growth rate (%)	Eleventh Plan Production ('000 t)
HDPE	55.72	293	21.06	762	8 06	1123	7 44	1607
PVC	11.00	312	9 11	482	8 06	710	7 44	1017
DMT	4.50	157	0 00	157	0 00	157	0 00	157
PTA	2.71	200	22 87	560	8 06	825	7 44	1181
PFY	11.00	305	9 11	472	8 06	695	7 44	995

Table 5.15. Energy demand estimates for selected petrochemical industries

Product	Eighth Plan Thermal ('000 Gcal)	Eighth Plan Electrical (GWh)	Ninth Plan Thermal ('000 Gcal)	Ninth Plan Electrical (GWh)	Tenth Plan Thermal ('000 Gcal)	Tenth Plan Electrical (GWh)	Eleventh Plan Thermal ('000 Gcal)	Eleventh Plan Electrical (GWh)
HDPE	178	90	1384	314	2039	462	2918	662
PVC	435	116	672	180	990	265	1418	379
DMT	674	125	674	125	674	125	674	125
PTA	1667	48	4667	136	6876	200	8844	286
PFY	3452	261	534	403	787	594	1061	1064

Polyvinyl chloride (PVC)

The demand projections for PVC are assumed to be the same as for HDPE. The growth rates assumed are 11%, 9.1%, 8.0% and 7.4% for the Eighth, Ninth, Tenth and Eleventh Plan periods respectively.

Dimethyl terephthalic acid (DMT)

DMT, which is at present used as the main raw material for the synthetic fibre industries is likely to be replaced with PTA because of the latter's advantages over DMT. During the Eighth Plan Period, the expansion of Bombay Dyeing Industries will increase the production of DMT to 157 000 tonnes (4.5% growth rate). It is anticipated that DMT will be replaced partially with PTA.

Purified terephthalic Acid (PTA)

Reliance Industries Ltd is the only manufacturer of PTA with an initial installed capacity of 100 000 tonnes per annum. The Government subsequently increased the minimum economic capacity of PTA plants to 200 000 tonnes which automatically increased the capacity of Reliance Industries to 200 000 tonnes. The production of PTA by Reliance industries is expected to reach 200 000 tonnes during 1996/97 from 175 000 tonnes during 1991/92 (2.71% growth rate) during Eighth Plan period. With the commissioning of National Petroleum Corporation (Madras) PTA production is expected to reach 380 000 tonnes during 2001/02 and the growth rate during this period is 22.87%. For the Tenth and Eleventh Plan periods the growth rates are assumed to be 8.06% and 7.44% respectively.

Polyester filament yarn (PFY).
The growth rates for PFY are assumed to be the same as for HDPE.

Transport

Passenger travel demand

Travel demand for passenger movement has been analysed separately for road based motorized transport and railways. In the case of road transport, a relationship was established between annual passenger travel demand, expressed in passenger kilometres (pkm), and the number of vehicles, occupancy and vehicle utilization. Travel demand by each mode was first computed by equation (1) and then aggregated across different passenger modes to obtain the total passenger travel demand.

$$P_i = V_i \times U_i \times O_i \qquad (1)$$

Where,

P = annual passenger travel demand (pkm)
V = number of passenger vehicles
U = annual vehicle utilization (km)
O = occupancy of a vehicle
i = passenger vehicle type

In the case of railways, travel demand for passenger movement is obtained directly from *Railway Statistics*, published by the Ministry of Railways.

Passenger travel demand has been extrapolated separately for road and rail by establishing linear econometric relationships between annual travel demand and growth of either total population or urban population.

Freight travel demand

Travel demand for freight movement has been analysed separately for road-based motorized transport and railways. In the case of road transport, the travel demand is estimated as the product of number of vehicles, average load carrying capacity per vehicle and average vehicle utilization per vehicle.

For each of goods vehicles, the freight travel demand was first estimated and then aggregated across different goods vehicles to obtain the total freight travel demand by road.

In the case of railways, travel demand for freight movement is directly obtained from *Railway Statistics*, published by the Ministry of Railways.

Freight travel demand has been extrapolated—separately for road and rail—by establishing linear econometric relationships between annual travel demand and GDP at factor cost.

GDP has been assumed to grow at the rate of 6 per cent per annum from the base year 1991/92. Table 5.16 gives the estimated travel demand under the business-as-usual (BAU) scenario for both passenger and freight movement, separately for road and rail, for the five reference years of the study. The share of total passenger travel demand by road between 1991/92 and 2011/12 will increase from 77%–85% and in the case of freight movement, the share of road transport during the same period will increase from 44%–51%.

Table 5.16. Estimated travel demand for the reference years under the BAU scenario

	Passenger travel demand (Btkm)				
Year	*Road*	*Rail*	*Total*	*Road (%)*	*Rail (%)*
1991/92	1087	323	1410	77 09	22 91
1996/97	1556	407	1963	79 27	20 73
2001/02	2226	514	2740	81 24	18 76
2006/07	3186	648	3834	83 10	16 90
2011/12	4559	818	5377	84 79	15 21
	Freight travel demand (Btkm)				
	Road	*Rail*	*Total*	*Road (%)*	*Rail (%)*
1991/92	201	259	460	43 70	56 30
1996/97	282	332	614	45 93	54 07
2001/02	392	424	816	48 04	51 96
2006/07	538	543	1081	49 77	50 23
2011/12	734	694	1428	51 40	48 60

Travel demand met by road and rail is further disaggregated into shares of different modes of motorized transport and locomotives and the shares of these different modes for meeting the total passenger travel demand is estimated by using time trend equations.

Table 5.17 gives the estimated split of passenger travel demand by different modes of transport.

Table 5.17. Estimated modal split with respect to passenger travel demand

	Road-based modal split (%)					*Rail-based modal split (%)*		
Year	*2-wheeler*	*Car/jeep*	*3-wheeler*	*Taxi*	*Bus*	*Steam*	*Diesel*	*Electric*
1991/92	16 45	5 43	3 7	0 14	74 28	14.37	51 57	34 06
1996/97	24 06	5 12	4 61	0 13	66 08	1 72	58 94	39 34
2001/02	33 61	4 6	5 49	0 12	56 18	0	53.72	46 28
2006/07	44 51	3 93	6 2	0 10	45 26	0	46 78	53 22
2011/12	55 69	3 16	6 62	0 08	34 45	0	39.84	60 16

Estimates of the modal split for freight travel demand (Table 5.18) are also estimated using time trend equations. It can be seen from Table 5.18 that the share of steam locomotives will be just 0.1% in 1996/97 and these will be completely phased out by 2001/02 as per the stated policy of the Government of India.

Table 5.18. Modal split with respect to freight travel demand

	Road-based modal split (%)			*Rail-based modal split (%)*		
Year	*Truck*	*LCV*	*3-wheeler*	*Steam*	*Diesel*	*Electric*
1991/92	93.13	6.17	0.70	0.29	55.88	43.83
1996/97	92.87	6.38	0.75	0.10	49.77	50.13
2001/02	92.66	6.55	0.79	0.00	42.20	57.80
2006/07	92.52	6.66	0.82	0.00	34.52	65.48
2011/12	92.42	6.74	0.84	0.00	26.84	73.16

Domestic sector

Under the BAU it is assumed that population will increase at an average rate of 2 per cent per annum over the period March 1991–March 2012. The total share of urban population is expected to increase gradually to reach 36.6% in March 2012.

Urban domestic energy demand

Total energy demand in urban households is directly related to population size and its distribution over various income classes. Per capita fuel consumption norms in different income classes as estimated from the survey carried out on urban households by the TERI, during 1987/88 have been used to estimate energy demands.

In the absence of any information on the distribution of population across different income groups, the quinquennial consumer expenditure data collected by the National Sample Survey Organization (NSSO) for the three years 1983 (38th round), 1987/88 (42nd round) and 1989/90 (44th round) were analysed and adjusted to reflect domestic savings to arrive at population distribution profiles across different income groups.

The cumulative distribution of population was computed for these three years, corresponding to five monthly household income groups and the rate of growth estimated to extrapolate population distribution across the five income groups for the reference years. Table 5.19 gives the resultant distribution of urban population. The urban population in

Table 5.19. Estimated urban population across income groups—All India

Income class	*Distribution of urban population (million)*				
(Rs/month)	*1991/92*	*1996/97*	*2001/02*	*2006/07*	*2011/12*
>400	4.6	4.9	5.2	5.5	5.6
400–800	73.2	88.2	102.9	121.1	140.7
800–1200	79.3	87.7	93.8	101.4	108.1
1200–2400	63.2	87.6	117.5	159.3	212.8
>2400	1.2	1.4	1.5	1.6	1.8
Total	221.5	269.8	320.8	388.8	468.9

India is estimated to go up from 221.5 million to 468.9 million between 1991/92 and 2011/12. The rate of growth of population is found to be the highest in the income group between Rs 1200 and Rs 2400 and least in the lowest income group.

The estimate of the proportion of urban population living in slums in India varies from 30–40%. The highest percentage of people living in slum areas is in the cities with a million plus population and the least in towns with less than 100 000 population. The growth rate of slum population, largely through migration, is significantly higher than that of other segments of the urban population.

Rural domestic energy demand estimation

Rural domestic energy demand is largely for the enduses of cooking and lighting. The fuels normally utilized for these enduses are fuelwood; dung-cake; agriculture residues and kerosene for cooking; and kerosene and electricity for lighting purposes. Given the variations in biomass availability, and hence consumption across agro-climatic regions, the analysis for this sector was conducted at a micro level and then aggregated to a national scale. The procedure adopted for projecting demand is as follows:

- the Rural energy database (REDB) estimates of household consumption (in physical units) available at the agro-climatic zone level for the fuels were disaggregated to the district level for all the states and then aggregated over the districts to arrive at state level estimates. The demand in physical units was converted to useful energy using appropriate conversion factors for the enduses of cooking and lighting,
- total population growth was projected as earlier at an average of 2 per cent per annum over the study period and rural population assumed net of the urban share. Total rural population was disaggregated on the basis of 1991 estimates to the state level (Table 5.20). The average household size is taken as 5.5,
- thereafter, the consumption figures were used to project the likely demand for different fuels for the enduses of cooking and lighting, at the district level for the different Plan periods,
- the impact of the penetration of renewable energy technologies (RETs), mainly biogas and ICs (improved *chulhas*) has been taken into account in the estimation. The savings accruing to the installation of biogas and ICs were discounted from the demand for cooking fuels at the state level. The demand after the incorporation of RETs thus obtained was used to determine the state-wise per capita demand.

Table 5.20. Population and number of households for different plan periods

State/UTs	Rural population (millions)					Households (millions)				
	1991	1997	2001	2007	2012	1991	1997	2001	2007	2012
Andhra Pradesh	49.58	52.21	55.20	57.43	59.27	9.01	9.49	10.04	10.44	10.78
Arunachal Pradesh	0.77	0.86	0.95	1.05	1.14	0.14	0.16	0.17	0.19	0.21
Assam	20.32	20.53	20.97	21.06	20.97	3.69	3.73	3.81	3.83	3.81
Bihar	76.49	82.09	88.22	93.33	98.00	13.91	14.93	16.04	16.97	17.82
Chandigarh	0.07	0.13	0.24	0.41	0.71	0.01	0.02	0.04	0.07	0.13
Dadra Nagar Haveli	0.13	0.15	0.16	0.18	0.20	0.02	0.03	0.03	0.03	0.04
Daman	0.04	0.04	0.04	0.05	0.05	0.01	0.01	0.01	0.01	0.01
Delhi	0.97	1.71	2.77	4.42	7.00	0.18	0.31	0.50	0.80	1.27
Diu	0.02	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00
Goa	0.70	0.67	0.64	0.61	0.58	0.13	0.12	0.12	0.11	0.11
Gujarat	27.59	28.57	29.80	30.61	31.21	5.02	5.19	5.42	5.57	5.67
Haryana	12.65	13.83	15.14	16.35	17.54	2.30	2.52	2.75	2.97	3.19
Himachal Pradesh	4.81	5.10	5.42	5.66	5.87	0.88	0.93	0.99	1.03	1.07
J&K	5.99	6.53	7.10	7.60	8.05	1.09	1.19	1.29	1.38	1.46
Karnataka	31.68	33.26	35.08	36.43	37.55	5.76	6.05	6.38	6.62	6.83
Kerala	21.84	22.16	23.46	25.47	28.98	3.97	4.03	4.27	4.63	5.27
Madhya Pradesh	51.84	55.85	60.17	63.79	67.10	9.43	10.15	10.94	11.60	12.20
Maharashtra	49.35	52.24	55.58	58.29	60.78	8.97	9.50	10.10	10.60	11.05
Manipur	1.36	1.52	1.69	1.85	2.02	0.25	0.28	0.31	0.34	0.37
Meghalaya	1.47	1.68	1.90	2.11	2.32	0.27	0.31	0.34	0.38	0.42
Mizoram	0.38	0.37	0.37	0.37	0.38	0.07	0.07	0.07	0.07	0.07
Nagaland	1.02	1.33	1.69	2.12	2.67	0.19	0.24	0.31	0.39	0.49
Orissa	27.96	29.35	30.92	32.06	32.96	5.08	5.34	5.62	5.83	5.99
Pondicherry	0.30	0.29	0.29	0.29	0.28	0.05	0.05	0.05	0.05	0.05
Punjab	14.57	15.27	16.08	16.66	17.12	2.65	2.78	2.92	3.03	3.11
Rajasthan	34.61	38.04	41.69	44.99	48.19	6.29	6.92	7.58	8.18	8.76
Sikkim	0.38	0.45	0.53	0.62	0.72	0.07	0.08	0.10	0.11	0.13
Tamil Nadu	37.50	38.31	39.49	40.04	40.26	6.82	6.97	7.18	7.28	7.32
Tripura	2.38	2.67	2.98	3.28	3.60	0.43	0.48	0.54	0.60	0.65
Uttar Pradesh	113.70	123.19	133.55	142.68	151.44	20.67	22.40	24.28	25.94	27.53
West Bengal	50.34	54.49	58.96	62.77	66.31	9.15	9.91	10.72	11.41	12.06
All India	640.81	682.90	731.10	772.60	813.30	116.51	120.19	132.93	140.47	147.87

Some of the major assumptions made were:

- The REDB consumption estimates used to project demand are assumed to have remained constant for all the years concerned. The changes in demand reflect change in population growth only.
- The enduse of lighting considers kerosene and electricity. The demand takes into account the 1991 consumption pattern (30% and 70% of electricity and kerosene for lighting, respectively). An increase in household electrification by 5 per cent for every Plan period is assumed.
- All Plan periods account for the penetration of RETs—biogas and ICs—for the enduse of cooking only, under different scenarios. It is assumed that in households using biogas, it replaces all cooking fuels; and in households using ICs, 20% saving in only fuelwood consumption is accounted for. The 1991 base case includes the installation (cumulative) of biogas plants and ICs up to March 1992 as per the Ministry of Non-conventional Energy Sources (MNES) records. The 1997 demand incorporates the targets for installation of biogas and ICs as set by MNES. Functionality rates of 60% and 50% for biogas and ICs (fraction of working plants) respectively, are taken. The addition in installation of biogas plants in all Plan periods beyond 1997 is 200 000 plants per year for the BAU scenario. For ICs, an annual growth rate of 10% is taken.

The demand projections thus arrived at are summarized in Table 5.21.

Table 5.21. Rural household energy demand estimation: Base case

Year	*Population (millions)*	*HH[a] (millions)*	*FW[b] Mt/a*	*DC[c] Mt/a*	*AR[d] Mt/a*	*KR(C)[e] Mt/a*	*KR(L) Mt/a*	*ELEC TWh*
1991	640 80	116 51	249 33	108 42	100 82	4 50	3 46	6 21
1997	682 90	124 16	259 50	114 16	106.15	4 74	3 43	7 76
2002	731 10	132 93	273 83	120 40	111 95	4 99	3 39	9.50
2007	772 60	140 47	283 75	124 99	116 23	5 18	3 37	11 58
2012	813 30	147 87	294 27	129 12	120 06	5 36	3 14	13 21

BG increase at 200 000 per year, ICs increase at 10% per year, Electrification of hh increase at 5 per cent (30% in 1991)
Decrease at 5 per cent in hh using kerosene for lighting
[a]households [b]fuelwood [c]dung-cake [d]agriculture residue [e]kerosene cooking [f]kerosene lighting, Elec—electricity, BG—biogas, IC—improved *chulhas*

Table 5.21a. Rural household energy demand estimation: Alternative scenario

Year	*Population (Million)*	*HH (Million)*	*FW (Mt/a)*	*DC (Mt/a)*	*AR (Mt/a)*	*KR (C) (Mt/a)*	*KR (L) (Mt/a)*	*ELEC[e] (TWh)*
1991	640 80	116.51	249 33	108 42	100 82	4 50	3 45	6 21
1997	682 90	124 16	259 5	114 16	106 15	4 73	3 16	8 87
2002	731 10	132 93	267 11	121 56	113 06	5 03	2 82	11 87
2007	772 60	140 47	280 40	127 21	118 93	5 29	2 45	15 44
2012	813 30	147.87	284 48	134 25	124 90	5 55	1 88	18.49

BG increase at 300 000 per year, ICs increase at 15% per year; Electrification of hh increase at 5 per cent (30% in 1991)
Decrease at 5 per cent in hh using kerosene for lighting

Agriculture

The projection of agricultural activity and subsequent irrigation and land preparation activities was done on a regional basis. The states were aggregated into regions as per the Central Electricity Authority classification[1].

For the purpose of this study, we have restricted our analysis to 7 major energy intensive crops of the country. The foodgrain crops considered were paddy, wheat, maize and gram. These account for 80% of the production and 60% of the area under foodgrains. The non-foodgrain crops considered were oilseeds, sugarcane and cotton. These crops also accounted for the major share of irrigated area (Table 5.22).

Due to the paucity of relevant information, the Union Territories and the states of the north-eastern region have not been included in the study. However, since their share in the area under the crops considered is not significant we can assume that excluding them has not made a substantial difference to the estimates.

Table 5.22. Irrigated area under the major crops (1988/89)

Crop	*Irrigated area as % of total area under the crop*	*Irrigated area as % of total irrigated area*
Rice	45.2	32.0
Wheat	78.4	30.9
Maize	20.6	2.0
Gram	19.8	2.1
Jowar	5.4	1.3
Bajra	6.2	1.1
Ragi	9.4	0.4
Barley	9.4	0.9
Groundnut	14.5	2.1
Rapeseed and mustard	55.1	4.0
Cotton	33.6	4.1
Sugarcane	85.7	5.1
Tobacco	23.4	0.3
Others	—	13.7

Source Fertilizer statistics, (1992/93), FAI, New Delhi

Irrigation

Since energy demand for irrigation is dependent largely on the quantity of water required and the height over which it is to be lifted, it was decided to estimate the water requirement for each crop in each region that is to be met from groundwater sources alone. For this purpose, region-wise past data was used on

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[1] North Jammu & Kashmir, Himachal Pradesh, Haryana, Punjab, Rajasthan and Uttar Pradesh
South Tamil Nadu, Karnataka, Kerala and Andhra Pradesh.
East West Bengal, Orissa and Bihar
West Maharashtra, Gujarat and Madhya Pradesh

- gross area under each crop
- gross irrigated \area under each crop
- share of irrigated area from underground sources

Projections were made for the above parameters, using power and linear functions on a three-year moving average to even out the impact of variations due to climatic factors. Using regression analysis based on a time trend, projections were obtained for gross cropped area under the crops being considered (Table 5.23), percentage share of the crop under irrigation (Table 5.24), and percentage share irrigated by underground sources in the total irrigated area (Table 5.25).

Table 5.23. Projections of gross area under various crops ('000 ha)

	Paddy	*Maize*	*Wheat*	*Gram*	*Sugar-cane*	*Oilseeds*	*Cotton*
North							
1988/89	8110.7	2969.7	15633.7	3763.3	2063.3	4567.4	1382.4
1996/97	8851.3	2926.2	16001.8	3614.5	2164.8	4295.7	1376.3
2001/02	9314.2	2908.2	16157.9	3554.3	2208.6	4187.2	1373.7
2006/07	9777.1	2893.9	16284.3	3506.6	2244.4	4102.1	1371.7
2011/12	10239.9	2881.9	16390.6	3467.3	2274.7	4032.3	1369.9
South							
1988/89	7534.2	514.9	325.4	258.4	558.9	5884.9	1390.1
1996/97	7370.3	523.6	313.9	269.9	602.9	7544.8	1281.2
2001/02	7302.9	527.3	309.3	274.9	630.3	8582.2	1238.4
2006/07	7249.4	530.3	305.5	278.9	657.8	9619.6	1205.0
2011/12	7205.0	532.7	302.4	282.4	685.2	10656.9	1177.8
East							
1988/89	15011.9	939.8	2387.7	297.5	185.32	1487.47	4.3
1996/97	15183.0	905.7	2624.8	287.5	182.3	1671.9	3.7
2001/02	15254.9	891.9	2773.0	283.5	181.0	1755.4	3.5
2006/07	15312.9	880.9	2921.2	280.3	180.0	1825.5	3.3
2011/12	15361.6	871.9	3069.4	277.6	179.2	1886.1	3.2
West							
1988/89	6879.7	1221.9	4988.6	2668.7	466.2	6462.2	4438.5
1996/97	6927.4	1327.7	4947.1	2736.7	490.6	7008.9	4283.2
2001/02	6947.3	1393.8	4929.9	2765.6	501.1	7250.5	4219.9
2006/07	6963.4	1459.9	4916.2	2788.9	509.7	7450.3	4169.9
2011/12	6976.8	1525.9	4904.7	2808.6	517.0	7621.4	4128.7
All-India							
1988/89	37536	5646	23335	6988	3274	18402	7215
1996/97	38332	5683	23888	6909	3441	20521	6944
2001/02	38819	5721	24170	6878	3521	21775	6836
2006/07	39303	5765	24427	6855	3592	22997	6750
2011/12	39783	5813	24667	6836	3656	24197	6680

Crop-wise per hectare water requirement for the regions was calculated using state-wise data on the water requirement for each crop, wherever available (Table 5.26). Groundwater requirement was then estimated. Once the total water requirement from underground sources was worked out, the associated energy requirements were calculated.

Table 5.24. Percentage projections of irrigated area under various crops

	Paddy	*Maize*	*Wheat*	*Gram*	*Sugarcane*	*Oilseeds*	*Cotton*
North							
1988/89	57.90	20.92	89.23	19.40	80.32	33.10	90.51
1996/97	63.60	21.01	91.50	19.89	79.83	44.06	89.05
2001/02	66.14	21.05	92.46	20.10	79.62	49.64	88.45
2006/07	68.26	21.08	93.24	20.27	79.46	54.62	87.97
2011/12	70.07	21.11	93.90	20.42	79.32	59.16	87.57
South							
1988/89	83.46	47.82	27.85	7.98	94.79	23.47	20.10
1996/97	83.13	49.42	34.08	10.14	97.15	25.13	23.42
2001/02	83.00	50.11	37.97	11.49	98.14	25.85	24.96
2006/07	82.89	50.67	41.86	12.83	98.94	26.44	26.28
2011/12	82.80	51.14	45.75	14.18	99.62	26.95	27.43
East							
1988/89	32.29	25.25	80.45	2.57	32.66	22.84	0.00
1996/97	34.23	30.60	86.78	2.71	31.84	30.57	0.00
2001/02	35.44	33.94	89.56	2.77	31.51	34.52	0.00
2006/07	36.65	37.28	91.86	2.82	31.24	38.06	0.00
2011/12	37.87	40.62	93.83	2.86	31.02	41.29	0.00
West							
1988/89	24.00	5.41	45.91	18.01	90.90	12.23	13.36
1996/97	25.04	8.31	48.62	21.93	89.32	12.80	13.96
2001/02	25.49	10.13	49.80	23.81	88.67	13.10	14.21
2006/07	25.86	11.94	50.76	25.43	88.15	13.30	14.42
2011/12	26.17	13.76	51.58	26.88	87.82	13.50	14.60

Table 5.25. Percentage of irrigated area using underground sources

	North	*South*	*East*	*West*
1988/89	62.19	36.52	50.68	63.77
1996/97	63.07	38.09	55.28	64.45
2001/02	63.44	38.76	57.31	64.88
2006/07	63.74	39.31	59.00	65.30
2011/12	63.99	39.78	60.45	65.73

Table 5.26. Crop-wise water requirement (hectare cm)

	Paddy	*Maize*	*Wheat*	*Gram*	*Sugar-cane*	*Oilseeds*	*Cotton*
North	131 (98–200)	25 (18–50)	36 (34–38)	15 (14–30)	194 (172–198)	23 (21–36)	85 (63–93)
South	132 (55–151)	40 (36–40)	30 –	48 –	153 (130–156)	38 (31–40)	50 35–58)
East	95 (44–142)	36 –	24 (18–35)	15 –	195 –	66 –	14 (8–18)
West	139 (36–170)	25 –	38 (37–42)	22 (15–48)	223 (114–282)	96 (84–120)	24 –

Note Figures in parentheses indicate the state-wise range (wherever available) over the region. W_c has been calculated using a weighted average, with area under the crop in the state as the weight.

An overall pump efficiency of 32.4% was assumed based on data compiled from various studies on efficiency of pumpsets. The overall field application efficiency was assumed to be 30%.

The figure used in the calculation for the average head over which water is to be lifted for the four regions pertains to the year 1988/89, since more recent figures are not available. Based on some studies conducted, it has been assumed that the groundwater levels are decreasing at the rate of 0.2 metres per annum. Therefore, the head over which underground water has to be lifted for irrigation purposes has been scaled up accordingly for the years being considered. (Table 5.27).

Table 5.27. Head over which water is to be lifted

	North	*South*	*East*	*West*
1996/97	21.1	16.6	16.6	15.6
2001/02	23.7	19.2	19.2	18.2
2006/07	27.3	22.8	22.8	21.8
2011/12	31.9	27.4	27.4	26.4

The projections of various quantities required to ultimately compute projected figures for energy requirement were the gross cropped area, the gross irrigated area and the percentage share of underground sources in total irrigated area.

Land preparation

The extent of mechanization varies from one state to another. Region-wise data on tractor population from 1978/79 onwards was used in a time trend to project the tractor population (Table 5.28).

Table 5.28. Region-wise projections of tractor population ('000)

	North	*South*	*East*	*West*	*Total*
1988/89	725.5	119.9	49.7	172.8	1067.9
1996/97	981.6	161.8	88.8	252.7	1484.9
2001/02	1113.5	183.4	113.2	296.1	1706.2
2006/07	1232.0	202.7	137.6	336.3	1908.6
2011/12	1340.6	220.5	162.0	373.9	2097.0

There is little information available on the quantity of diesel used for land preparation activities which made it necessary to follow a normative approach. Table 5.28, however, gives region-wise projections of diesel requirement for land preparation

The annual employment of tractors for land preparation and other agricultural operations was taken at 252.3 hours, based on the data collected in a survey carried out in the three northern states of Haryana, Rajasthan and Uttar Pradesh (TERI, 1991). The average use of tractors per season was calculated on the basis of hours of use and current tractor population in each state as weights. As this was the usage per season, it was multiplied by the overall cropping intensity of 1.3 to arrive at the annual usage.

The horsepower rating of tractors varies from 15–35 (Mittal *et al*, 1985) with an average rating of 30. The fuel consumption norm for tractors was taken as 0.125 litres/HP (Mittal *et al*, 1985). Thus, the fuel consumption for a tractor is 3.75 litres per hour.

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CHAPTER 6

Energy supply projections

As the energy sector in India is still predominantly in the public sector, domestic energy supply prospects have, as far as possible, taken into account the forecasts of the Government of India. However, past experience indicates that such forecasts of supply growth are likely to be underachieved.

Coal

The production plans for coal are based on the major assumptions that

- the coal industry would be able to meet the total demand for non-coking coal from the power and industry sectors and
- the demand of the steel sector would be partially met by import of low-ash prime coking coal to the extent of 30–40% of the demand.

The future coal demand projections are based on a keynote address on *Coal Beneficiation in India—Need and Justification* delivered by Mr R K Sachdev, Adviser, Ministry of Coal, in a seminar on Clean Coal Technology organized by the Indian Institute of Chemical Technology at Hyderabad on April 15–16, 1994.Coal demand projection is given in Table 6.1.

Table 6.1. Coal demand projection (Mt)

	1992/93	*1996/97*	*2001/02*	*2009/10*
	(Actual)	*(Target)*	*(Tentative projections)*	
Steel	32.4	42.0	44.0	45.0
Power	149.5	190.0	241.0	340.0
Others	62.2	86.0	111.0	175.0
Total	244.1	318.0	396.0	560.0

Historically, coal production plans have been drawn up to match demand. However, with the reduction in import duty on non-coking coal from 85–35%, it is expected that some industrial consumers in the southern and western coastal regions may import superior grade non-coking coal. In addition, some cement plants in these areas which export cement can import non-coking coal free of duty. Also, the new power plants coming up in the private sector in these areas have the option to import non-coking coal for their consumption. Assuming that 10% of the demand of power plants and 10% of the demand of industries is met by imports—in addition to increased imports by steel plants—the demand to be met from internal sources is given in the Table 6.2. The large quantity of coal imports would require an expansion of port handling facilities on the southern and western coasts. At present, the major coal handling ports—Haldia, Paradeep and Vishakapatnam are all on the eastern coast. Madras port handles small quantities of coal imports.

Table 6.2. Coal production requirements (Mt)

	1996/97	2001/02	2011/12
Total demand	318	396	560.0
Imports	10	48	65.0
Power sector	1	24	34.0
Others	1	11	17.5
Iron and steel	8	13	13.5
Demand to be met from indigenous	308	308	495

Accordingly, the tentative production plan can be expected to be as follows:

			(Figures in Mt)
	1996/97	*2001/02*	*2011/12*
Opencast	215	243.6	371.2
Underground	93	104.4	123.8
Total	308	348.0	495.0

The share of production from opencast mines is pegged at 70% in 1996/97 and 2001/02 and at 75% in 2011/12. Production and productivity from underground mines have not shown any improvement in the last two decades, due to surplus manpower; depletion of reserves in many old mines; and poor working environment including mechanization. To fulfil the production plans for underground mines, it would be necessary to open up medium and large capacity mines especially in the Jharia and Raniganj coalfields which are the main source for superior grade coals (coking and non-coking). In addition, thrust on production from ongoing underground mines would be essential.

Large capacity opencast mines are being planned in selected coalfields to meet the production targets. The production plans of these coalfields are given in Table 6.3.

Table 6.3. Production plan of selected coalfields (Mt)

Coalfield	*1984/85*	*1991/92*	*1996/97*	*2001/02 (Tentative)*
Rajmahal	0.8	4.2	10.5	13.6
N Karanpura	4.7	7.0	14.7	25.6
Singrauli	10.7	30.9	39.0	44.6
Ib valley	2.0	6.9	12.9	18.5
Talcher	3.4	13.8	25.6	31.8
Singareni	12.3	20.6	33.0	36.0

Sources. Coal India Limited/Ministry of Coal and TERI's estimates

Oil and gas

Exploration strategy

The exploration strategy of the national oil companies, has been undergoing changes over the years. While the initial emphasis was on increasing exploration activities in Category I basins in Assam and Gujarat, offshore exploration started in right earnest in the sixties. By about the beginning of the eighties, as exploration had already reached a mature stage in Category I basins on the one hand, and Category II and III basins on the other, it was felt that significant new discoveries could be possible only in Category II or III basins. However, during the Seventh Plan period, certain Category I basins like Dahej and Gandhar onshore and Neelam offshore fields also produced encouraging results. Similarly, some Category II basins such as Krishna-Godavari, Cauvery and Assam-Arakan (Tripura-Cachar), turned out to be encouraging with hydrocarbon production commencing in the last few years. These basins have now been upgraded as Category I basins. The future exploration strategy of the national oil companies has been formulated with the objective of concentrating their efforts on areas with known trends where encouraging leads have already been obtained. This strategy is dictated as much by the limited resources of national oil companies as by the hope of a large exploration input from private oil companies following the new rounds of bidding.

The Government has invited private and foreign oil companies to come in for exploration and development of already discovered oil fields. In the fourth round of bidding invited in September 1991, 33 onshore and 39 offshore blocks were offered to private parties, both Indian and foreign, on a production sharing basis. Contracts for four such blocks have been signed. In the fifth round of bidding invited in January, 1993, 45 blocks including some blocks offered in the 4th round were put up for bidding. The success of the exploration efforts of the private companies will be an important factor in deciding the annual production level in the late 1990s and thereafter.

It has already been recognized by the Government that accretion of geological reserves should be of the order of 1400–1500 Mt for oil and natural gas together, every five years (Table 6.4).

Table 6.4. Targets for reserve accretion during 1992/97

	Geological reserve accretion	*Recoverable reserve accretion*
Oil	980.60 Mt	276.30 Mt
Gas	344.40 Bcu.m	178.10 Bcu.m

The total investment for exploration and development of oil and gas in the public sector for 1992–97 has been fixed at Rs 20 000 crores. The current capital cost for development of new production capacity of 1 Mt of oil and oil equivalent of gas per annum is of the order of Rs 1000 crores in offshore and Rs 500 crores in onshore fields. Clearly, the public sector outlay during the 8th plan will be inadequate for the projected quantum jump in oil and gas production in 1996/97 (Table 6.5).

Table 6.5. Targets for hydrocarbon production during 1992–97

Region	*Crude oil (Mt)*	*Natural gas (Bcu m)*
Onshore		
Western	38.97	16.21
Eastern	37.03	16.57
Southern	2 36	5.30
Offshore		
Western	115 21	86.52
Southern	3 75	0 82
Total	197.32	125.42

A great deal of supplementation of private capital will be necessary to achieve the projected production targets. Judging by the response received from private parties, such private capital may not be difficult to obtain (Box 6.1).

Box 6.1

PRIVATE SECTOR PARTICIPATION : OIL SECTOR

Against the backdrop of rising demand for petroleum products and declining domestic production, Government has decided that increased private sector participation in both downstream and upstream sectors is imperative if India is to attain a reasonable degree of self-sufficiency in meeting its requirements for petroleum products.

The basic policy changes aimed at an enhanced role of the private sector are summarized below.

Upstream

- Exploration for hydrocarbons through continuous round-the-year bidding rounds.
- Offer of discovered small and medium oil and gas fields
- Offer of blocks to conduct seismic surveys.

Downstream

- Introduction of parallel marketing scheme for LPG, kerosene and LSHS.
- Free pricing of lubricants.
- Setting up of refineries as joint sector as well as private sector projects.

Exploration and Production

India has been inviting bids from foreign oil companies since as long as 1979 when the first round of bids was announced. To date, 8 rounds of bids have been made The contractual system followed in India is of the production sharing type. The Production Sharing Contract features include possibility of a seismic option, no minimum expenditure commitment during the exploration period, no signature or production bonus and no royalty payment. Private companies which have made bids include Command Petroleum (Australia), Vaalco Energy, Rexwood Corporation, Oakland Oil (US) Despite India's terms being among the best in the world, private participation has not been to the extent envisaged. This can be attributed to India's prospects being perceived as poor compared to competing regions like China, Vietnam, and

Box 6.1 contd...

This has prompted the Government to make offers to companies to develop discovered fields and take up blocks for conducting seismic surveys. Companies which have been awarded discovered fields include Enron, Command Petroleum and Marubeni. In another major policy change Indian E & P companies—ONGC and OIL, are being allowed to enter into joint ventures with private companies for exploration purposes.

Marketing

Under the Parallel Marketing Scheme, private companies—both Indian and foreign—are free to import, set up storage facilities for and sell LPG, kerosene and LSHS at market determined rates to consumers. Shell has tied up with Bharat Petroleum, a public sector company to import and market LPG. Inadequate infrastructure in terms of port facilities is the major constraint faced by private companies. The lubricants market has seen the entry of major oil players like Mobil, Elf, Exxon, Total, Castrol, which have tied up with public sector companies to supply lubricants.

Refining

With present refining capacity at 53.4 MMTPA and demand by 2010 expected to be around 150 MMTPA, augmentation of indigenous refining capacity is essential. To facilitate this, joint ventures and private refineries are being allowed to be set up. India's first joint sector refinery, the Birla-HPCL joint venture is expected to go on stream by 1996. Other joint ventures include two refineries of 6 MMTPA being set up by the Oman Oil Company with Indian public sector companies. In the private sector, two major players—Reliance Industries and the Essar Group—will set up 9 MMTPA refineries by 1998.

However, procedural and other issues may lead to delays in firming up private participation in new oil and gas development. With the production of 30.35 Mt of crude oil and 18.6 Bcu.m of natural gas in 1991/92, the reserve-to-production ratio of crude oil and natural gas stood at 26:1 and 39:1 respectively, in 1991/92.

The production of crude oil and natural gas during 1992–97 has been targeted as shown in (Figure 6.1 and Figure 6.2).

If both the reserve accretion and production targets are achieved (as given in Tables 6.4 and 6.5), the balance recoverable oil and gas reserves will be 880 Mt and 790 Bcu.m respectively, at the end of the Eighth Five Year Plan, i.e. on April 1, 1997. At an annual production of 50 Mt of oil and 30 Bcu.m of natural gas (these figures correspond to current production targets for 1996/97), the R:P ratio for oil and natural gas in 1997 will stand at 17:1 and 26:1 respectively.

It is clear that in the coming years, the scope of substantially increasing the production of natural gas is relatively much larger than that for crude oil. The crude oil production target for the Eighth Five Year Plan is rather ambitious and is unlikely to be achieved because of the delays in initiating oil and gas development projects. This would marginally improve the R:P ratio for oil. The scope of development of natural gas reserves will nevertheless remain much greater.

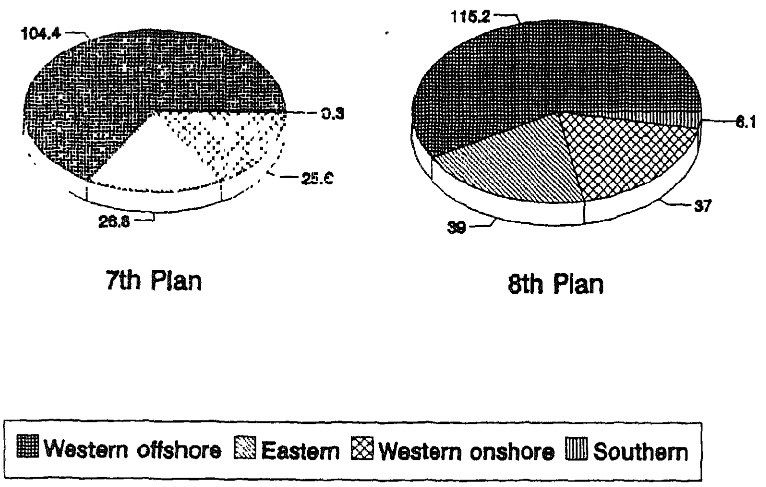

Figure 6.1. Region-wise cumulative production of oil (Mt)

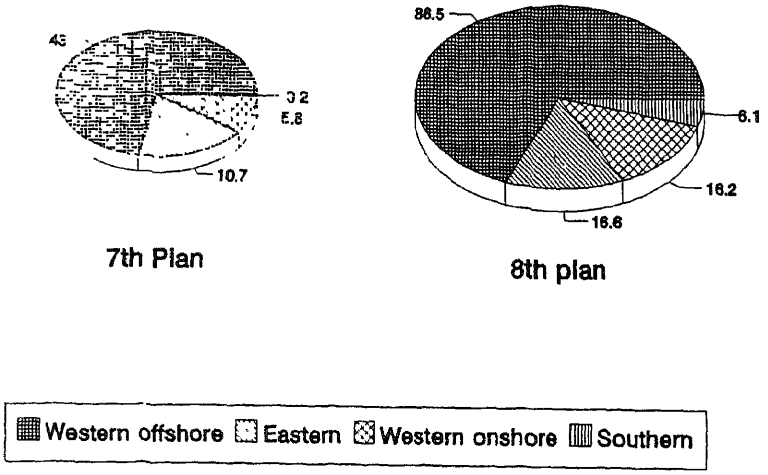

Figure 6.2. Region-wise cumulative production of natural gas Bcu.m

In light of the present trends, the oil production in 1996/97 may be around 40–42 Mt only, as against the target of 50 Mt.

The expected total refining capacity region-wise by 1996/97 is shown in Table 6.6.

Table 6.6. Refining capacity (Mt)

	1991/92	1996/97
Western region	21.0	24.0
Northern region	7.5	7.5
Eastern region	8.8	10.5
Southern region	14.6	22.0
Total	51.9	64.0

The capital outlay for the refining and marketing sector during the period 1992–97 has been fixed at Rs 4000 crores. This amount will not be adequate by itself to finance the refining capacity augmentation programmes. This can be judged from the fact that the capital outlay for the proposed 3 Mt/a capacity refinery in Assam is Rs 1830 crores at current prices. However, since work on the two grassroot refineries at Mangalore and Cauvery basin has already started and the others are relatively low-cost expansion programmes in existing refineries, there may not be any resource constraint for augmentation of the refining capacity during the Eighth Five Year Plan. Availability of private capital, both Indian and Foreign, and access to the capital market will nonetheless be extremely important for setting up new grassroot facilities in the next 15–20 years.

In India, high speed diesel and kerosene alone, account for nearly 55% of the total consumption of all petroleum products. Keeping this in view, the refineries try to make optimum use of secondary processing facilities to maximize distillate production. The product of all the refineries taken together in 1991/92 was light distillates (19%), middle distillates (51%), heavy ends (22.9%), lubes and greases (0.8%) and fuel and loss (6.3%).

The demand-supply balance of petroleum products in 1996/97 is projected to be as follows:

• Production from Indian refineries	59.52 Mt
• LPG production from natural gas	2.05 Mt
• Import of products	22.92 Mt
• Export of products	3.3 Mt
• Total domestic consumption	81.3 Mt

Power

The power supply industry in India has registered a phenomenal growth during the past four decades. The emphasis has been on adding capacity to meet the rapid increase in demand. Presently, India is investing 2 per cent of it's GDP annually and this trend is likely to continue in the future.

The country's additional needs during the 15 year period from 1991/92–2006/07 have been projected by CEA at 142 000 MW, bringing the required installed capacity in 2006/07 to 211 000 MW. Table 6.7 below, gives the optimum generation expansion plan.

Table 6.7. CEA's perspective plan 1992–2007 optimum scenario—high hydro (MW)

Type of plant	*Installed capacity (1991/92)*	*Addition* 1992–97	1997–02	2002–07	*Total addition (1992–07)*	*Installed capacity (2006/07)*
Hydro	19 508	9397	17 705	24 534	51 636	71144
Thermal	48 331	26 074	24 088	31 485	81 647	129978
Nuclear	2035	1175	4940	2030	8145	10180
Total	69 874	36 646	46 733	58 049	141 428	211302

Source. Central Electricity Authority, New Delhi, 1993

To meet load demands optimally, the ideal hydro:thermal ratio of the installed capacity should be 40:60. This ratio existed till the early '70s, when rapid increase in demand called for conventional plants with short gestation periods, giving thermal plants their present dominance.

While drawing up the country's generation expansion programme, an assessment was made by CEA of the capacity needed with a low hydro scenario and a high hydro (optimal) scenario. The two scenarios are depicted in Table 6.8.

Table 6.8. Plant additions 1992–2007 (MW)

Type of plant	*Optimal plan*	*Low hydro scenario*
Hydro	51 636	26 986
Thermal	81 647	121 547
Nuclear	8145	8145
Total	141 428	156 678

It is seen that there is a saving of 15 000 MW in the high hydro scenario. Apart from this huge saving in installed capacity, the optimal expansion programme would also result in significant reductions in pollutant emissions.

However, in India, hydro development is handicapped due to the following reasons:

- interstate water disputes,
- uncertain geological strata in the Himalayan region,
- low demand for power in the States where the potential lies (Jammu & Kashmir, Himachal Pradesh, North Eastern Region),
- non-availability of financial resources in states with physical resources,

- unwillingness of states to allow the centre to exploit the State hydro potential, and
- a growing awareness and concern for the displacement of thousands of people with the accompanying rehabilitation measures.

The result is that hydro development during the last decade has hardly been more than 1000 MW/year. To achieve the enumerated targets, the pace of hydro development would have to be increased to 2000–3500 MW per year and that of total capacity additions by over 9000 MW per year. Capacity additions of these magnitudes are highly improbable even if private participation is accounted for (Box 6.2).

Box 6.2

POLICY GUIDELINES TO ENCOURAGE GREATER PRIVATE SECTOR PARTICIPATION IN THE INDIAN POWER SECTOR

The power sector was opened for private participation with the objective of bringing in additional resources for investment in the power supply facilities to reduce the widening gap between electricity demand and supply. Further, private sector participation is also expected to bring in increased efficiency in the operations of the power sector

Targeting for 5000 MW of private power during the Eighth Five Year Plan, the Government of India, through various amendments to the Electricity Supply Act 1948, has drawn up a policy package offering financial, legal and administrative incentives to attract private investment in the power sector.

Modifications in the Financial Environment

- All private companies entering the electricity sector will be allowed a debt-equity ratio upto 4:1. The promoter's contribution should be at least 11% of the total outlay. At least 60% of the outlay must be raised from sources other than public financial institutions.
- Up to 100% foreign equity participation can be permitted for projects set up by foreign private investors.
- A guaranteed 16% return on equity, in the currency in which investment is made. Fixed costs including 16% return on equity (ROE) can be recovered at 68.5% plant load factor (PLF). Attractive incentives are prescribed for performance beyond this PLF in the form of additional ROE (up to 0.7%) for each one per cent rise in PLF
- The rates for depreciation in respect of assets have been liberalized. This rate has been changed from 5.06%–7.5%.
- Capitalization of interest during construction at the actual cost (instead of 1 per cent above the Reserve Bank of India rate as prevalent before), for the initial project as well as subsequent projects.
- With the approval of the government, import of equipment for power projects will also be permitted in cases where foreign supplier(s) or agency(ies) extend concessional credit.
- The customs duty for import of power equipment has been reduced to 20% and this rate has also been extended to machinery required for modernization and renovation of power plants.
- A five-year tax holiday is offered to private entrepreneurs setting up generation station. The five-year tax holiday will begin from the year of generation of power.
- The excise duty on a large number of capital goods and instruments in the power sector has been reduced to a uniform lower rate of 5 per cent.
- Flexibility has been allowed in including insurance charges in the project cost, provided, the operation and maintenance charges do not exceed 2.5%. In order to take into account larger insurance costs, it has been decided that the O & M

Box 6.2 contd...

Modifications in the Legal Framework

- The ceiling limit for projects in the power sector to be submitted to the Central Electricity Authority for its concurrence has been raised from Rs 5 crores to Rs 25 crores.
- Licensee companies will be granted licenses for a longer duration of 30 years in the first instance and subsequent renewals of 20 years, instead of 20 and 10 years respectively as was the case before the amendment to the Electricity (Supply) Act.
- The interpretation of the Generating company has been made to mean a company registered under the Companies Act, 1956, which has among its objectives the establishment, operation and maintenance of generating stations.
- The generating company can enter into contract for the sale of electricity generated by it with the SEB in any State where it owns/operates the power station(s) or any other State where it is carrying on its activities or with any other person with the consent of the competent Government.

Modifications in Administrative Framework

For faster clearance of the private sector projects, the Government of India has set up a high-powered board to monitor the issues of clearances required for the generation, transmission and distribution projects. The Board serves as a single-point forum for faster clearances of the proposals received within a definite time frame and to resolve any outstanding issues pertaining thereto.

The Ministry of Power has set up an investment promotion cell to provide information and assistance to prospective investors in the electricity sector regarding: (i) schemes to encourage private sector participation in electricity generation and supply (ii) the clearances to be obtained and (iii) the modalities of obtaining these clearances. The Investment Promotion Cell is also responsible for monitoring and processing of private power proposals and to take action for time-bound clearances of the proposals.

Response from the Private sector

Following the new economic policy initiated in 1991, many private firms—both Indian and foreign, have expressed interest in setting up power projects. The Ministry of Power has received 75 proposals for private sector participation aggregating to a total capacity of 32 661 MW. Several MOUs have been signed and of these 8 have secured final clearance from the central government and are in the advanced states of finalization of the Power Purchase Agreement with the SEB and the state government (details are given in Table [illegible]). Out of the 75 proposals received, two are for distribution, both in the state of Orissa, and one is for renovation and modernization of the existing power plant in Orissa.

The Central Electricity Authority's estimates have been revised by TERI to a more likely generation expansion programme given in Table 6.9 below. This takes into consideration a reduction in installed capacity growth of about 40 000 MW on account of demand management, energy conservation, and integrated grid operation. Table 6.10 gives the likely power development scenario in the 15 year period 1992–2007.

Table 6.9. Likely power development scenario 1992–2007 (MW)

Type of plant Year	*Installed capacity March 92*	*Addition Eighth Plan 1992–1997*	*Addition Ninth Plan 1997–2002*	*Addition Tenth Plan 2002–2007*	*Addition 3 plans 1992–2007*	*Installed capacity March 2007*
Hydro	19 189	4973	11 194	16 892	33 059	52 248
Thermal: coal	45 454	11 476	22 450	20 260	54 186	99 640
Thermal: gas	2654	4191	4438	2180	10 809	13 463
Nuclear	1785	660	2100	2440	5200	6985
Total	*29082*	*21300*	*40182*	*41772*	103254	132336

Table 6.10. Breakup of hydro schemes (MW)

Schemes	*Eighth Plan*	*Ninth Plan*	*Tenth Plan*	*15 Years*
SOG[a]	4958	5799	4395	15152
CEA[b] Cleared	15	1389	5644	7048
New	—	4006	6853	10859
Total	4973	11194	16892	33059

[a]sanctioned and ongoing [b]Central Electricity Authority

Funds provided for the power sector in the Eighth Five Year Plan (1992–97) are not adequate to cover the above expenditure, and additional funds to the extent of Rs 20 000 crores are required. In view of the fact that there is a reduction in installed plant capacity by 15 000 MW, taking up advance action for accelerated hydro development in the Eighth Plan is very important. With the various measures proposed for improved plant performance, conservation measures and proper demand management, there is scope for reduction of over 40 000 MW of thermal capacity resulting in CO_2 abatement by about 36%.

Renewable energy

The potential for exploiting renewable energy in the country is discussed here only for those sources that are already techno-economically feasible.

Wind energy

Wind technology in India is fairly advanced and well established. Estimates of the MNES place the realisable wind energy potential in India at 20 000 MW. Another study carried out by TERI estimated the realizable potential of wind resource along the coastal regions to be in the range of 50 000 MW. There is, however, a significant difference between the *ultimate* and the realizable potential of wind energy and this is largely due to the highly intermittent nature of wind energy source and the characteristics of the grid (Table 6.11). In general, the penetration level (indicative of the realizable potential that windfarms can contribute to the regional grid) in India varies between 5 and 50% depending on the generation mix on the grid.

During the Eighth Five Year Plan (1992–97), MNES plans to increase the installed wind energy capacity by 500 MW comprising:

100 MW government-sponsored cum market development projects,
200 MW IREDA/World Bank/GEF financed projects,
200 MW private sector's own investment projects.

The outlay for the wind energy programme for the Eighth Plan period is Rs 90 crores. In recent years, multilateral funding agencies, particularly Danish International Developement Authority (DANIDA), have come forward in a big way to procure funds for the wind energy programme in India. Amounts of US $13 million from GEF and US $15

Table 6.11. Ultimate potential of windfarms in selected districts with highest wind resource

District	Waste land (sq km)	Ultimate potential (MW)	Wind speed (m/s)	Specific output at 25 m/h (kWh/kW/yr)	Cost of electricity of WEG (Rs/kWh)	Potential Generation (GWh)
Kachch	38 640	82 998	5 25	1607	2.87	2 668 123
Jamnagar	7280	15 637	5.68	1945	2 37	608 281
Rajkot	3300	7088	5 57	1858	2 48	263 340
Junagad	3080	6615	5 58	1866	2 47	246 814
Bhavnagar	4400	9451	5.35	1685	2 74	318 466
Ratnagiri	5980	12 845	5 22	1584	2 91	406 994
Puri	2700	5799	5 15	1531	3.01	177 528
Baleshwar	1440	3098	5 04	1447	3 19	89 682
Ramanathapuram	5850	12 565	5.16	1538	3 00	386 575
Coimbatore	2220	4768	5 38	1708	2 70	162 895
Tirunelvelli	4950	10 632	5 84	2073	2 23	440 770
Kanyakumari	440	945	6 43	2546	1 81	48 126

million from IDA have already been made available for the wind energy programme. Another US $50 million from DANIDA have also been sanctioned.

Small hydro power sources

Generation of electricity from small sized hydro power sources is a low-cost, environment friendly and renewable source of energy. Though the technology is centuries old, it has received wide public attention only in the last few decades.

Classification of mini and micro hydel systems.

In India, the small, mini and micro hydel systems together are treated as small hydro power (SHP) systems covering a wide range of sizes and capacities. The classification adopted is as follows:

- Micro-hydro: less than 100 kW
- Mini-hydro: 101–2000 kW (unit size up to 1 MW)
- Small-hydro: 2001–15000 kW (unit size up to 5 MW)

Presently, the responsibility of promoting MMHP up to 3 MW lies with MNES while the Central Electricity Authority (CEA) looks after hydro power from 3–15 MW.

Potential

A recent assessment exercise undertaken by CEA has established a potential of about 4037 MW in nine states so far. The study in the rest of the southern States is being now carried out, while it is expected to begin soon in other States, including the north-east. Based on the trends, however, MNES estimates that the total small-hydro potential for India up to

15 MW capacity is likely to be over 10 000 MW. About half of this is expected to be in mini- and micro-hydro categories in the hilly areas and in the north-eastern region.

The Eighth Plan target for capacity addition through micro, mini and small hydel projects as per the revised strategy and action plan *suo moto* formulated by MNES is 600 MW.

Biogas technology

Biogas is a technology which makes optimal use of locally available resources like animal dung and other organic material, providing clean and convenient fuel, at the same time producing nutrient rich manure. Biogas makes sound economic sense both in terms of effective heat as well as cost. Studies carried out by TERI indicate that the levelized annual cost (LAC) comes to Rs 0.53/KWh which compares well with that of a traditional *chulha* which costs Re 0.54/kWh. Biogas is cheaper than fuelwood and dung except when they are acquired free of cost, and competes closely with kerosene. Biogas also offers versatility in application. It can be used for lighting, cooking and motive power.

Though the technology is over a hundred years old in India, it was launched as a government programme only in 1981 under the name of National Project on Biogas Development (NPBD). NPBD has been the cornerstone of the renewable energy programme in India accounting for over half of the total funds allocated to the renewable energy programme. About 1.93 million plants had been installed by the end of March 94 out of a total potential of 12 million (MNES estimates). The target for the Eighth Plan period is 1 million installations with an outlay of Rs 3.2 billion.

Improved cook-stoves

Traditionally, most Indian households use cook-stoves (*chulhas*) for cooking. These cook-stoves are constructed indigenously, often by the owners themselves. These are made of mud, brick or metal sheets and operate at a thermal efficiency of 7–10%. Two types of *chulhas* are used—fixed and portable.

The improved designs of cook-stoves have been primarily developed with two objectives: to increase thermal efficiency and to reduce or remove smoke. The first objective is achieved by increasing useful heat transfer to the cooking vessel by incorporating modified flue gas passages and features like a baffle, swirl chamber, etc. They also feature a chimney which provides a safe outlet for escape of flue gases, thus shielding the cook from any harmful consequences of exposure to smoke. Portable models consist of modified and slightly more complicated designs for the combustion chamber, grate, etc. which help in enhancing useful heat transfer capability of the device. While improved versions of the fixed model have been found to have an efficiency in excess of 20%, the portable designs were found to have efficiency values of the order of even 30%

in the laboratory. An increase in thermal efficiency can be expected to bring about a reduction in fuelwood consumption and in the long run, conservation of precious forest resources. The ultimate potential target group for improved cook-stoves is the entire rural population, i.e. 120 million households.

Solar water heating

Use of simple, low-temperature collectors for providing hot water is the oldest and most widely accepted applications of solar energy. In India, solar industrial process heat (IPH) has been the most popular application followed by domestic water heating systems. Till December 1992, 5159 solar water heaters for industrial use and 10 432 for domestic use had been disseminated. The estimated market size is 10–20 million m^2 in the industrial sector and about 1–2 million m^2 in the domestic sector. In spite of such large physical potential, the solar hot water business is not exactly booming. In fact, several earlier stalwarts like Jyoti, HBB (currently ABB), and Best & Crompton have discontinued the manufacture of solar water heating systems. The economics of the systems are perhaps responsible.

Biomass energy

An overwhelming proportion of the rural domestic energy is supplied by the biomass fuels. In the rural areas, biomass fuel is mostly collected at a *zero private cost*, and no formal distribution systems exist like in the case of commercial fuels. Hence, it is difficult to correctly estimate, either at the micro or macro level, how much biomass is supplied from what type of land. This process is rendered even more difficult in the absence of reliable biomass assessment techniques for large-scale enumeration. Given this difficulty, most rural energy consumption surveys in the past assumed the supply to be equal to consumption. However, this is clearly not tenable in view of the implications on the sustainability of resources.

Fuelwood

The fuelwood consumption in rural areas is in the range of 100–250 Mt. However, a considerable amount of fuelwood is also consumed in the urban domestic sector and in commercial establishments. It is estimated that nearly one-third of the total fuelwood is consumed in the non-rural sectors. Thus, the total consumption is probably in the range of 150–300 Mt.

The current sustainable production of fuelwood from forests, as estimated by the Forest Survey of India, is placed at 36 Mt (52 Mcu.m) (GOI 1989). This includes the unrecorded production of fuelwood in the form of dead/dying and seasonally fallen wood which is collected from the forests as headloads by the villagers living near the forests, and production from the plantations developed by the Forest Department[1]. The estimation from the so-called *unrecorded sources* which include supply of fuelwood from private lands, gardens, trees around houses, shifting cultivation areas and the like, has been put at 50 Mt/a (Agarwala 1989). This brings the total sustainable fuelwood supply to 86 Mt (Table 6.12).

Table 6.12. State-wise fuelwood supply estimates (Mt/a)

State	*Forest with > 40% crown density*	*Forest with 10-40% crown density*	*Plantations*	*Total supply (Mt per annum)*
Andhra Pradesh	1.876	0.5469	0.058	2.481
Arunachal Pradesh	4.091	0.3554	0.005	4.451
Assam	1.188	0.2227	0.015	1.426
Bihar	0.996	0.3346	0.042	1.373
Goa (Daman & Diu)	0.075	0.0064	0.001	0.082
Gujarat	0.467	0.1322	0.107	0.706
Haryana	0.025	0.0046	0.037	0.067
Himachal Pradesh	0.668	0.0717	0.021	0.761
Jammu & Kashmir	0.825	0.2268	0.009	1.060
Karnataka	1.864	0.1836	0.083	2.131
Kerala	0.632	0.0468	0.047	0.726
Madhya Pradesh	7.154	1.0100	0.254	8.418
Maharashtra	1.963	0.4440	0.154	2.561
Manipur	0.398	0.3094	0.008	0.715
Meghalaya	0.248	0.3143	0.005	0.567
Mizoram	0.321	0.3644	0.031	0.716
Nagaland	0.265	0.2698	0.009	0.544
Orissa	2.051	0.4915	0.086	2.629
Punjab	0.036	0.0216	0.046	0.104
Rajasthan	0.227	0.2452	0.046	0.518
Sikkim	0.180	0.0158	0.006	0.202
Tamil Nadu	0.732	0.1977	0.099	1.029
Tripura	0.137	0.0928	0.013	0.243
Uttar Pradesh	1.699	0.2740	0.225	2.198
West Bengal	0.254	0.0629	0.062	0.379
Andamans	0.494	0.0017	0.007	0.503
Chandigarh	—	—	0.0003	0.000
Dadra	0.012	0.0012	0.002	0.015
Delhi	—	0.0006	0.0005	0.003
Lakshadweep	—	—	—	0.001
Total	27.778	6.2486	1.481	36.61

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[1] The figures from plantation cover, the area under plantations during 1980-87

As far as the future is concerned, there are no estimates on the supply nor is there any evidence of increased availability of fuelwood. Given the fact that forests and other biomass resources are undergoing degradation in various degrees in different parts of the country, it is unlikely that the fuelwood supply would go up substantially. Therefore, it is possible that the sustainable yield of fuelwood would continue to be in the range of 85–90 Mt/a, a far cry from the expected demand of over 270 Mt in the rural areas alone.

Crop residues

Crop residues are the plant materials that are left in the field or in agro-based industries after extracting the main crop produce. Crop residue can be in the form of straw, stalk, husk, leaves, fibrous material, roots and other parts of the plant material. No reliable data are available with regard to the quantity of crop residues used either as fuel or as fodder. A rough estimate for non-fodder crop residues for the year 1991 is around 127 Mt per year, nearly half of which is used up in the sugar industry. Based on the likely increases in the yields of non-fodder crops, the availability of crop residues has been estimated for the future years. The availability estimates of crop residues in the terminal years of the Five Year Plans are presented in Table 6.13.

Table 6.13. Availability of crop residues in the terminal years of different Plans

	Crop residues ('000 tons)						
Terminal year	*Maize*	*Pulses*	*Groundnut*	*Sugarcane*	*Cotton*	*Jute*	*Total (Mt)*
1990	2688	18 545	2480	79 545	22 320	2334	127
1997	2680	18 010	2679	79 544	21 623	2447	127
2002	2879	18 913	2880	87 290	21 284	2477	135
2007	3079	19 817	3081	95 035	20 946	2507	144.4
2012	3278	20 720	3282	102 781	20 607	2537	153 2

Dung-cakes

There are about 272 million bovine animals in the country according to the Livestock Census of 1987. The total production of dung from these animals is around 1000 Mt per annum on a wet weight basis, which puts the dry dung availability at approximately 200 Mt. Half of the dung produced is assumed to be used as fuel; that is 100 Mt, which corresponds to the dung consumption figures provided by various estimates. The bovine population over the last two decades has been more or less constant and, therefore, the dung availability for fuel purposes is not likely to improve significantly in the future.

CHAPTER 7

Optimizing energy supply demand balances

The previous chapters looked at possible growth paths for each sector of the economy. An attempt is made here to take a holistic view of the economy, growth targets/prospects, and consequent demand for energy services and to match these demands—in an *optimal* manner—to energy supplies, taking into account technological choices, technology costs, availability of desired energy forms, effectiveness of energy use in alternate applications, effectiveness of delivery and cost of supply.

The environmental component is introduced through constraints on the levels of emissions and effluents arising out of the entire fuel cycle. This exercise is also designed to allow alternatives for technical innovations and fuel switching on the demand side.

The model can be used to specifically address the following issues:

- the likely fuel supply mix that should be adopted for the next twenty years,
- the associated environmental impacts of following such an energy strategy, in terms of the volume of emissions and effluents,
- the level of imports of the various types of fuels, given the demands and the available financial resources,
- the extent of inter-fuel substitution on the enduse side, and
- the implementation mechanism (economic and financial) that is required for the optimal supply strategy.

The model[1]

The TERI Energy Economy Simulation and Evaluation (TEESE) model is a linear programming model capturing the energy, economy and environment linkages. It is demand driven and is built on the Reference Energy System (RES) which maps primary energy sources to secondary sources and ultimately to the enduses. The objective of the model is to minimize the annualized energy system cost for given technologies and other constraints. This is done for the terminal years of the Eighth, Ninth, Tenth and Eleventh Five Year Plans in order that an energy efficient and environmentally better strategy is evolved over time.

The outputs that the model provides are in terms of the

- optimal primary energy supply mix,
- optimal level of import and export of various fuels,

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[1] See Appendix 1

- optimal fuel mix use pattern in various sectors,
- optimal modal mix in transport sector,
- technology-wise optimal generation and capacity mix,
- optimal energy system cost,
- resource requirement, and
- emission levels of different pollutants.

Scenarios

The various scenarios that have been developed are as follows:

Business-as-usual scenario (BAU)

This scenario is constructed under the assumption that the present energy supply and use pattern will persist with some marginal changes within the time frame of the study. For example, in the transport sector, the model assumes that the trend of rapid shift to private modes of transport from the public mode will continue as exhibited in the past. Similarly, in the agricultural sector, the existing diesel pumpsets will be completely replaced by electric pumpsets. Likewise, it is assumed that the share of kerosene for rural electrification will decline in future. In industry, marginal improvements in energy efficiency are considered.

On the supply side, it is assumed that crude oil and natural gas production would be at the levels of 47 Mt and 36 Bcu.m respectively in 2001. However, this production level has been frozen beyond 2001. For crude oil, this is justified because of the low reserve-production (R-P) ratio of crude oil. For gas, since a significant percentage of gas produced is associated in type, any decline in crude production would result in a decline in gas production. It has been assumed that domestic non-coking coal production will grow at a rate of 6 per cent per annum, whereas coking coal supply has been kept at 50 Mt and 60 Mt respectively in 1996 and 2001. Beyond that, the annual production will remain constant at 70 Mt. For power plants, marginal improvement in plant load factor, auxiliary consumption and conversion efficiency for thermal power plant are assumed in the model over the time frame of the study. Also, reduction in transmission and distribution losses and improvement of the system load factor of the utility system is taken into account. Here, it should be pointed out that this improvement does not need any additional investment and can be achieved by better management. Further, import of natural gas at a price of US $2.5 (c.i.f.) per thousand cubic metres (m^3) (different parties are bargaining with the Government of India at this rate presently), has been allowed from 2006. Details about techno-economic data assumptions are given in Appendix 2.

Scenario I: Energy conservation

This scenario considers energy conservation measures such as improvement in coke rate, reduction in industrial process heating energy and electricity requirement, improvement in agricultural pumpsets, reduction in transmission and distribution (T & D) losses over the BAU etc. Since conservation measures generally take time to be implemented and since 1996 is only two years ahead, these options have been considered from the Ninth Plan.

Whereas in the BAU scenario T & D losses had been assumed at 21%, 19%, 17% and 15% in respective terminal years (to be achieved by eliminating commercial losses), in this scenario, a further 2 per cent reduction in T & D losses in successive terminal years excepting 2011 has been assumed. For the year 2011, a further 3 per cent reduction has been assumed. These reductions in the respective terminal years will be achieved by reducing technical losses needing an investment of Rs 1711 per MW (TERI estimates).

The Inter-Ministerial Working Group on energy conservation estimated that there is a potential of 20%, 20% and 15% energy savings in coal-based, oil-based and electrical equipments respectively, in the existing system. This will be achieved by the installation of heat recovery systems, replacement of inefficient boilers, computerization of process control operations, adoption of cogeneration systems, etc. requiring a total investment of Rs 57.46 billion (TERI estimates). The present average coke rate in Indian integrated steel plants is around 680 kg per tonne of hotmetal. In this scenario, it is assumed that the coke rate will be gradually brought down to 570 kg per tonne of hotmetal in 2006/07 (SAIL) and the same rate will continue to 2011.

In addition 5 per cent, 10%, 15% and 15% of urban lighting requirement will be met by compact fluorescent lamps in 1996/97, 2001/02, 2006/07 and 2011/12 respectively. By retrofitting electric pumpsets for irrigation, it is possible to increase efficiency of the pumpsets by 20%. This needs an investment of Rs 1500 per pumpset. In this scenario, we have assumed that all pumpsets will be retrofitted. Further, this scenario assumes the introduction of compact fluorescent lamps (at a marginal rate) for lighting in the commercial sector.

Scenario II: Accelerated renewable

In this scenario, higher capacity additions in renewable energy technologies (RETS) like wind and small hydel are considered. Also, in this scenario, biogas availability is higher than in the BAU scenario. The addition of nuclear capacity is not contingent on its cost features but is fixed at 10 000 MW by 2011. Due to the same reason as in Scenario I, this scenario is also developed for the years 2001/02 and onwards.

Scenario III: Clean coal technologies

Whereas scenarios I & II would have a positive impact on the environment this scenario too—which introduces clean coal technologies for power—can be termed as environmentally friendly scenario. The two technologies considered here are the Integrated Gasifier Combined Cycle (IGCC) and the Molten Carbon Fuel Cell (MCFC) technology. It is assumed that these two technologies will be commercially available in India in 2006 and afterwards. Possible additions for 2006/07 and 2011/12 are given in Table 7.1.

Table 7.1. Capacity addition of new clean coal technologies under consideration [gigawatt (GW)]

	2006/07	2011/12
IGCC	2.5	5.0
MCFC	2.5	5.0

Scenario IV: Higher hydro capacity

This scenario considers the development of higher hydro potential. Assessed hydro potential in the country is 85 000 MW. Physically exploitable hydel potential for the year 2011 has been placed at a maximum of 60 000 MW under the BAU scenario. For the same year, this limit has been extended to 70 000 MW under the present scenario.

Scenario V. Constrained firewood

In this scenario firewood supply has been frozen at 200 Mt from 2001 onwards.

Scenario VI: Hybrid scenario

In this scenario, all the measures undertaken in Scenarios I to V are considered simultaneously. Scenarios IV, V and VI have been developed only for the year 2011.

Low population scenario

Further, we have developed another scenario which considers low population growth rate as compared to the BAU scenario. In the BAU scenario population growth rate has been taken at 2.01% during the period 1991–96 and at 2 per cent beyond that. While in this scenario, population growth rate has been taken as 1.77%, 1.69%, 1.54% and 1.40% respectively for the periods 1991–96, 1997–2002, 2002–2007 and 2012 as worked out by the Standing Committee on Population Projection (1989), formed by the Government of India, all other assumptions are the same as in the BAU scenario. Results of this scenario have been presented for the year 2011 only.

Results and analysis

Business-as-usual scenario

Commercial and non-commercial energy demands for different terminal years as estimated by the model are presented in Table 7.2.

Table 7.2. Fuel-wise energy demand for different terminal years

Fuel	*Unit*	*1991*	*1996*	*2001*	*2006*	*2011*
Coal	Mt	229.00	300.0	386.6	494.0	628.0
Natural gas	Bcu.m	14.40	26.3	36.6	43.8	61.5
Petro products	Mt	59.60	65.0	86.0	114.0	144.5
Primary electricity	TWh	78.20	127.3	166.2	213.0	235.5
Crop waste	Mt	100.00	110.0	121.0	129.0	145.0
Firewood	Mt	247.00	270.0	295.0	315.0	344.0
Dung-cake	Mt	107.00	119.0	130.0	139.0	156.0
Biogas	Bcu.m	0.66	1.3	1.9	2.4	3.0

The share of non commercial energy has declined from 49% in 1991 to 46% in 1996 and then further to 35% in 2011. Commercial energy-GDP intensity [million Gcal per rupees billion (1991/92 prices)] for different years are worked out as follows in Table 7.3.

Table 7.3. Commercial energy—GDP intensity in different terminal years [Unit: Million Gcal per Rs billion (1991/92 prices)]

	1991	*1996*	*2001*	*2006*	*2011*
Energy—GDP Intensity	0.351	0.335	0.327	0.310	0.295

There is a 15.7% reduction in energy intensity within the 20 year period from 1991–2011. This decline in energy intensity is due to the higher efficiency path along which the economy is already moving. Sector-wise energy requirement is discussed below.

Agriculture sector

Useful energy demands for land preparation and irrigation for various terminal years are shown in Table 7.4.

Table 7.4. Enduse-wise useful energy demand in the agricultural sector (Unit: Million Gcal)

	1996/97	*2001/02*	*2006/07*	*2011/12*
Irrigation	30.0	36.0	44.0	53.1
Land preparation	17.2	19.8	22.1	24.3

Table 7.5 gives the energy requirement for this sector as obtained from the model solution along with the actual consumption in 1991.

Table 7.5. Fuel requirement in the agriculture sector

Fuels	*Units*	*1991*	*1996*	*2001*	*2006*	*2011*
HSD[a]	Mt	0.60	3.7	3.8	5.5	5.9
Electricity	TWh	58.78	87.2	104.6	120.0	145.0
Animal power	Million Gcal	na	15.8	15.8	15.8	15.8

[a] high speed diesel

A steep rise is observed in HSD and electricity requirement for irrigation and land preparation during the period 1991–1996. Gradual decrease in growth of HSD requirement in later years can be explained by the following:

- replacement of diesel pumpsets by electric sets,
- gradual decrease in the growth of agricultural sector due to structural changes in the economy which leads to lower final energy requirement, and
- improvement in efficiency.

Electricity requirement has also declined slowly which is again due to improvement in pumpset efficiency and decline in final energy requirement as mentioned earlier.

Industry

Industry consumes around 60% of the total final commercial energy as fuel and feedstock as shown in Table 7.6.

Table 7.6. Fuel requirement as energy and feedstock in the industrial sector

Fuels	*Units*	*1991*	*1996*	*2001*	*2006*	*2011*
Energy use						
Coal[a]	Mt	96.00	135.0	180.0	238.0	315.0
Fuel oil[b]	Mt	9.93	10.2	11.6	12.6	15.1
Natural gas	Bcu.m	0.70	0.9	1.1	1.4	1.8
Electricity	TWh	112.00	137.0	185.0	246.0	326.0
Non-energy use						
Natural gas	Bcu.m	6.00	10.1	13.2	16.5	21.1
Fuel oil	Mt	na	1.5	1.9	2.4	2.8
Naphtha	Mt	3.50	3.5	5.0	6.6	7.2

[a] includes coal for captive power generation also [b] figure for 1991 includes both fuel and feedstock

Over the period 1991–2011, coal requirement in the industrial sector increased at a rate of more than 6 per cent annually. This is partly because, over the period, coal replaced fuel oil due to a short supply in domestic fuel oil (by the freezing of crude production at the 2001 level and lower refinery capacity addition).

During 1985–91, electricity consumption increased by 5.7%. As against this, only 4.11% growth rate in electricity requirement is observed in the period, 1991–96, because of the lower growth rate of the industrial sector during that period. The model finds it more economical to use natural gas for feedstock and power generation rather than as heating fuel for which abundant coal reserves are present.

Domestic sector

Requirement of different fuels in the domestic sector are shown in Table 7.7.

Table 7.7. Fuel requirement in the domestic sector

Fuels	*Units*	*1991*	*1996*	*2001*	*2006*	*2011*
LPG	Mt	2.27	2.97	3.83	4.7	5.6
SKO[a]	Mt	7.30	10.60	12.70	13.7	15.8
Soft coke	Mt	0.30	5.00	5.00	6.0	7.0
Electricity	TWh	36.00	84.00	121.60	166.0	208.0
Bio gas	Bcu m	1.96	1.30	1.90	2.4	3.0
Crop waste	Mt	100.00	110.00	121.00	129.0	145.0
Fire wood	Mt	247.00	270.00	295.00	315.0	344.0
Solar	Million Gcal	na	3.80	4.30	5.7	7.8
Dung-cake	Mt	107.00	119.00	130.00	139.0	156.0

[a] superior kerosene oil

Past trends in LPG and electricity consumption persist in the future as well. A substitution of kerosene by electricity for rural lighting results in slow growth rate in kerosene demand. Although, soft coke consumption has gone down over the past, Government's present policy is to promote soft coke use in the domestic sector particularly in regions lying on the coal belt by supplying smokeless briquetted fuel etc. The potential demand for soft coke assessed by TERI has been incorporated in the model.

Transport sector

For this sector, the model first determines the optimal modal mix taking into account the past trend for passenger as well as freight transport and then estimates the fuel requirement accordingly (Table 7.8).

Rapid increase in MS requirement is the reflection of present trend towards more dependence on private mode of transport.

The commercial sector including trade, services, hotel and public water supply and public lighting, has shown higher growth rate than the industry and agriculture sectors in the recent past and this trend will continue in the future as well.

Table 7.8. Optimal fuel mix for the transport sector

Fuels	Units	1991	1996	2001	2006	2011
HSD	Mt	na	21.4	26.4	33.3	37.6
MS[a]	Mt	3.7	5.1	11.3	18.8	30.3
Electricity	TWh	4.5	6.3	9.1	12.7	21.2

[a] motor spirit

Energy requirement has been estimated as follows (Table 7.9):

Table 7.9. Fuel-wise energy requirement in the commercial sector

Fuels	Units	1991	1996	2001	2006	2011
SKO	Mt	1.40	3.00	4.60	6.90	10.50
LPG	Mt	na	0.85	1.17	1.50	1.80
Soft coke	Mt	0 170	0.23	0.16	0.12	0.08
Electricity	TWh	22.00	26.80	36.20	55.30	84.60

Supply

Domestic supply

Availability of various primary and secondary fuels from domestic sources is given in Table 7.10.

Table 7.10. Domestic availability of various fuels in the different terminal years

Fuels	Units	1991	1996	2001	2006	2011
Coal	Mt	229 00	294 0	380 0	486.0	618.0
Natural gas	Bcu.m^3	14 40	26.3	36.6	36 6	36.6
Crude	Mt	30.30	35.0	47.0	47.0	47.0
LPG	Mt	2.65	2 5	3.2	3 9	4.9
SKO	Mt	8.38	6 6	8.0	9.9	11.7
Fuel oil	Mt	9 20	10 6	13.1	16.1	19.7
Naphtha	Mt	3.46	3 5	5.0	6.6	7.2
HSD	Mt	24 00	21 2	25.7	32.0	38.5
MS	Mt	3.57	4 3	5.3	6.6	8.0
ATF	Mt	1 56	3.2	2.6	3.3	4.0
Electricity generation (utilities)	TWh	287 00	426.1	560.5	718 0	907.0

Import

Import requirements for the various fuels as estimated by the model are presented in Table 7.11

As far as exports are concerned, only export of naphtha has been chosen as an optimal solution.

Table 7.11. Import requirements of various fuels

Fuels	Units	1991	1996	2001	2006	2011
Crude	Mt	24.00	30.00	32.7	52.70	72.7
Natural gas	Bcu.m	—	—	—	7.36	24.9
Coal	Mt	5.90	5.50	6.6	8.40	10.8
ATF	Mt	0.02	0.90	2.1	4.50	6.2
LPG	Mt	0.22	1.34	1.8	2.30	2.5
SKO	Mt	3.40	7.30	7.2	8.70	10.3
FO[a]	Mt	—	0.40	1.4	—	—
HSD	Mt	5.30	4.20	4.6	6.20	5.3
MS	Mt	—	0.80	6.0	12.20	22.3

[a] fuel oil

Electricity supply from utilities will be provided by the technology mix as given in Table 7.12.

Table 7.12. Technology mix for power generation capacity (GW)

Technology	1991	1996	2001	2006	2011
Coal	45.5 (65)	51.8 (52.3)	65.0 (50.0)	80.30 (48.6)	99.0 (47.4)
Gas	2.6 (3.7)	17.0 (17.2)	25.0 (19.2)	31.00 (18.8)	51.0 (24.4)
Hydel	19.6 (28.19)	28.0 (28.3)	37.0 (28.5)	49.60 (30.0)	54.0 (25.8)
Nuclear	1.7 (2.48)	1.8 (1.8)	1.8 (1.37)	1.78 (1.08)	1.8 (0.85)
Small hydel	0.1 (0.012)	0.3 (0.28)	0.7 (0.54)	1.40 (0.82)	2.0 (0.96)
Wind	0.1 (0.06)	0.2 (0.18)	0.5 (0.38)	1.00 (0.62)	1.5 (0.72)
Total	69.7	99.0	130.0	165.00	209.0

Note Figures in the brackets are shares (%) in the total

Here, it should be noted that power generation capacity from 1996 onwards, will not only meet the energy requirement of the economy, but also assures the meeting of peak load which has been estimated at 62 600 MW, 82 270 MW, 104 000 MW and 132 000 MW for 1996, 2001, 2006 and 2011 respectively. The decline in the share of gas-based capacity from 2006 is because of the limit imposed on domestic production of natural gas which has been frozen at the level of 2001.

Finally, emission levels of various pollutants and optimal energy system cost under the BAU scenario as estimated from the model is presented in Table 7.13.

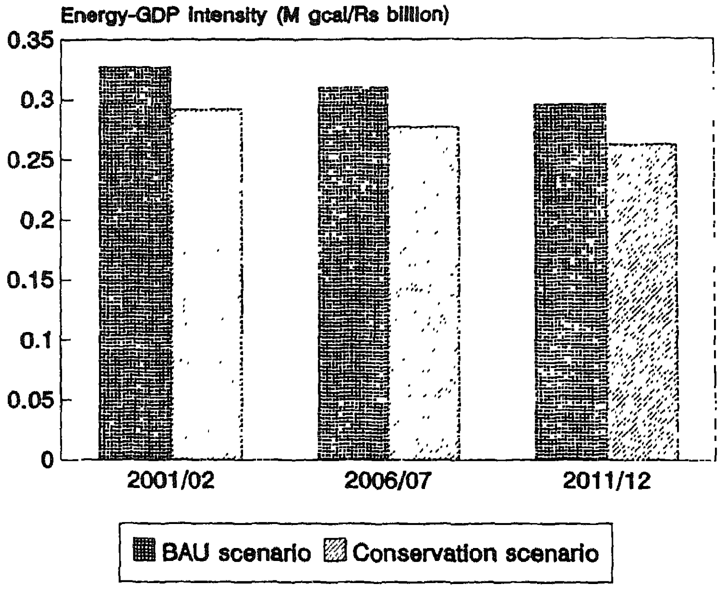
Table 7.13. Emissions of various pollutants and optimal energy system costs

Pollutants	*Units*	*1996*	*2001*	*2006*	*2011*
CO_2	MtC[a]	428 000	511.000	605.500	736.200
CO	Mt	16.160	17.900	19.600	22.000
SPM	Mt	200.300	259.100	338.000	434.000
NO_x	Mt	1.340	1.750	2.190	2.820
SO_x	Mt	0.049	0.089	0.125	0.158
System cost	Rs billion	1671.00	2277.000	3084.000	4112.000

[a] million tonnes of carbon

Scenario analysis

Under the energy conservation scenario (Scenario I) the energy system costs decline by Rs. 110 from the base cost in 2001, by Rs. 140 in 2006/07 and by Rs. 174 in 2011/12, net of the investments made for energy conservation. In the same years, commercial energy—GDP intensity declined by 9.4%, 10.5%, and 11.3% as compared to the BAU (Figure 7.1).



M gcal - Million giga calories

Figure 7.1. Commercial energy GDP intensity BAU and conservation scenario

The conservation measures in the industry, agriculture and residential sectors results in a reduction in electrical energy and peak load demand (Figure 7.2).

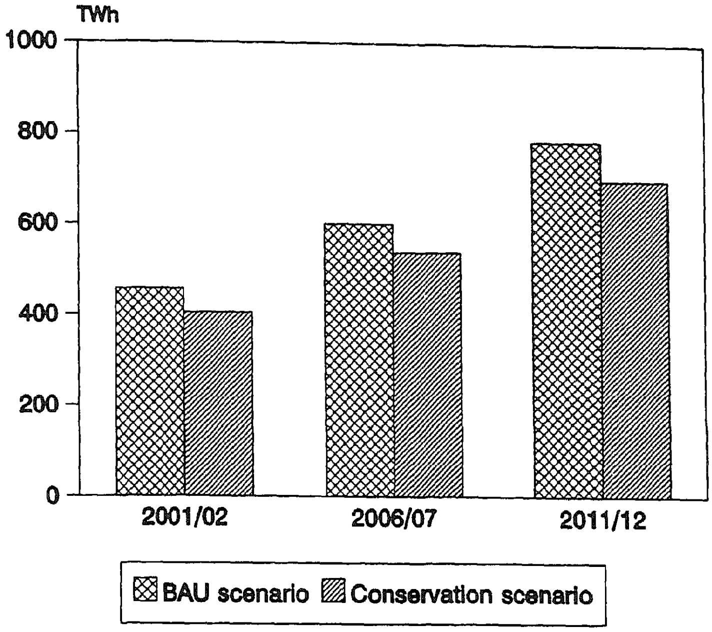


Figure 7.2. Electricity demand in BAU and conservation scenario

This, accompanied by the reductions in transmission and distribution losses, implies a lower utility generation to the tune of 51 TWh, 61 TWh and 86 TWh in 2001/02, 2006/07 and 2011/12 respectively.

The savings in coal and petroleum products are shown in Table 7.14.

Table 7.14. Fuel savings in Scenario I over the BAU scenario

Fuel	*Unit*	*2001/02*	*2006/07*	*2011/12*
Coal	Mt	34.0	56.0	74.0
Petroleum products	Mt	10.5	14.5	17.5
Natural gas	Bcu.m	—	—	3.0

The impact of energy conservation measures on environment has been significant in Table 7.15.

In the renewable energy scenario (Scenario II), which considers accelerated development of renewable technologies like wind, small hydel etc, commercial energy—GDP intensity is worked out as 0.32 million Gcal, 0.30 million Gcal, 0.285 million Gcal per Rs billion for the years 2001/02, 2006/07 and 2011/12 respectively as against 0.327 million Gcal, 0.31 million Gcal and 0.295 million Gcal per Rs billion for those years under the BAU scenario. Under this scenario, introduction of additional renewable capacity for power generation has reduced coal and gas consumption in the

Table 7.15. Reductions in emissions of various pollutants in Scenario I over the BAU scenario

Pollutants	*Unit*	*2001*	*2006*	*2011*
SPM	Mt	12.0	18.0	26.0
SO_x	Mt	0.0	0.0	0.0
NO_x	Mt	0.2	0.2	0.4
CO	Mt	0.1	0.6	0.9
HC	Mt	0.0	0.1	0.1
CO_2	MtC	32.0	43.0	53.0

power sector. The coal released by the power sector has replaced fuel oil which is largely imported, and is used primarily in the industry sector. Primary energy requirement in this scenario as against the BAU scenario is given in Table 7.16.

Table 7.16. Primary energy requirements, BAU *vis-a-vis* Scenario III

		2001/02		*2006/07*		*2011/12*	
Fuel	*Unit*	*BAU*	*Sc II*	*BAU*	*Sc II*	*BAU*	*Sc II*
Coal	Mt	386.0	374.0	494.0	488.0	628.0	628.0
Petro products	Mt	85.0	84.0	114.0	103.0	144.5	124.0
Gas	Bcu m	36.6	36.6	43.8	43.8	61.5	52.8
Primary power	TWh	127.0	191.0	213.0	257.0	236.0	313.0
Crop waste	Mt	121.0	121.0	129.0	129.0	145.0	145.0
Dung-cake	Mt	130.0	130.0	139.0	139.0	156.0	156.0
Firewood	Mt	295.0	295.0	315.0	315.0	344.0	344.0
Biogas	Bcu.m	1.9	2.2	2.4	3.0	3.0	3.8

Total system costs in this scenario have gone up by Rs 22 billion, Rs 37 billion and Rs 48 billion over the BAU in the years 2001/02, 2006/07 and 2011/12 respectively.

The decline in fossil fuel consumption results in reduction of CO_2 emissions (Figure 7.3). On the other hand, SPM emissions have gone up because of the increase in coal consumption in the industrial sector which has a higher SPM emission factor.

In the environmentally friendly scenario (Scenario III), which considers introduction of clean coal technologies for power generation from 2006, there are marginal changes in energy supply and use strategy over the BAU. Coal consumption in the power sector has declined by 15 and 28 Mt but coal demand in the energy system has remained the same as in the BAU scenario. On the other hand, fuel oil demand has declined by 7 and 13 Mt. This is because coal (which was otherwise consumed in the power sector) has replaced fuel oil as industrial fuel which is expensive and imported.

Introduction of expensive clean coal technologies results in an increase in the total energy system cost by Rs 32 billion and Rs 46 billion in 2006/07 and 2011/12 respectively.

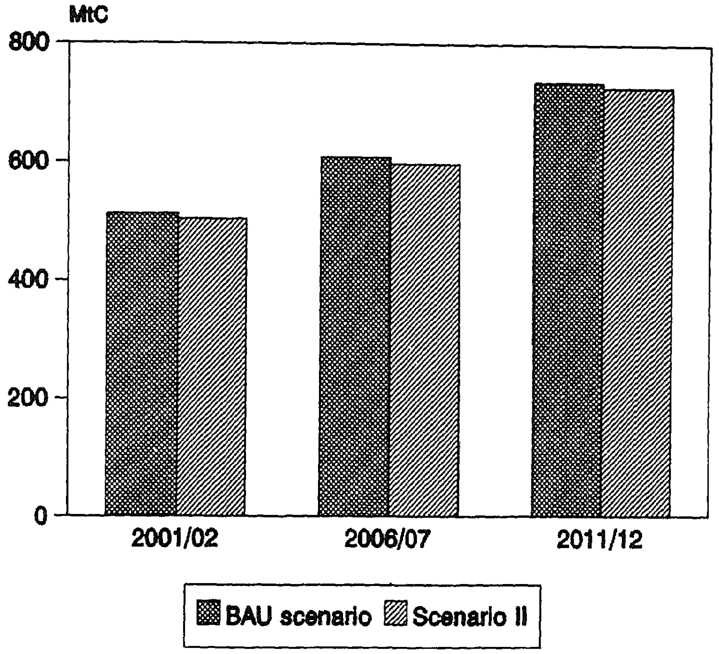


Figure 7.3. Carbon dioxide emissions in BAU scenario and scenario II

As far as the environmental impact of the introduction of clean coal technologies (CCTs) is concerned, excepting SPM and CO_2, negligible changes are observed in the emissions of other pollutants over the BAU scenario. SPM emissions increased by 6 Mt according to the BAU scenario in 2006 due to the higher use of coal in industry. CO_2 emissions, however, decreased by 4.5 Mt. In 2011, both SPM and CO_2 emissions went down by 3 Mt and 11 Mt respectively.

Scenario IV which allows higher addition of hydel capacity in 2011 as compared to the BAU scenario, coal and gas demand in the power sector have declined by 9 Mt and 6 Bcu.m respectively. There is marginal reduction in the system cost and CO_2 emissions. While system cost has declined by Rs 1 billion, CO_2 emissions are low by 9 Mt as compared to BAU.

In Scenario V, where firewood supply has been frozen at 200 Mt in 2011, as expected petroleum products (SKO) demand has gone up by 13 Mt. This results in increase of system cost by 89 billion rupees and reduction in CO_2 emissions by 44 Mt.

Scenario VI considers energy conservation measures along with accelerated penetration of environmentally friendly technologies and restriction in fuelwood supply at 200 tonnes. Under this scenario, the model gives a drastic reduction in coal demand, as compared to that over the BAU scenario in 2011/12. This reduction was contributed by the industry sector as a result of conservation measures, as well as by the power sector. In the power sector, coal demand went down due to:

- decline in the demand for electricity, and
- accelerated addition in renewable technology, clean coal technology, etc.

Under the same scenario, requirement of petroleum products, mainly SKO, has gone up by 13 Mt, while the model cuts down the natural gas requirement through a reduction in imports.

The fossil fuel demand under this scenario, and the BAU scenario is given below.

		2011/12	
		BAU scenario	*Scenario VI*
Coal	Mt	628.0	460.0
Petroleum	Mt	144.5	157.0
Natural gas	Bcu.m	61.5	36.7

The overall requirement of petroleum products has gone up because of higher petroleum product demand by the domestic sector on account of a reduction in fuelwood supply.

System cost and emissions under this scenario are given below.

	Units	*2011/12*
CO_2	MtC	591.000
CO	Mt	18.800
SPM	Mt	330.000
NO_x	Mt	2 040
SO_x	Mt	0.145
System cost	Rs billion	4119.000

Low population scenario

Due to low population growth rate, as expected, energy requirement and system costs are reduced considerably in this scenario. Comparisons of the results of this scenario with BAU are presented below for the year 2011.

	Units	*BAU*	*Low Population Scenario*
Requirement of			
Coal	Mt	628.0	617.0
Petroleum products	Mt	144.5	122.0
Natural gas	Bcu m	61 5	59.8
Electricity (consumer end)	TWh	785.0	765.0
CO_2 emissions	MtC	736.0	700.0
System costs	Rs Billion	4112.0	3600.0

Summary and conclusions

The table 7.17 gives a comparison of the results of the various scenarios carried out for the model in this chapter.

Table 7.17. Comparison of the results of the various scenarios [Unit: Rs (million)]

	1996/97	2001/02	2006/07	2011/12
BAU	1671	2277	3085	4112
Scenario I	—	2167	2945	3938
Scenario II	—	2299	3122	4160
Scenario III	—	—	3117	4158
Scenario IV	—	—	—	4111
Scenario V	—	—	—	4202
Scenario VI	—	—	—	4119
Low Population Scenario	—	—	—	3600

		2011/12							
Pollutant	*Units*	*BAU*	*Sc I*	*SC II*	*Sc III*	*Sc IV*	*Sc V*	*Sc VI*	*Low Population Scenario*
SPM	Mt	434.00	408.00	503.00	431.00	433.00	434.00	330.00	430.00
SO_x	Mt	0.16	0.09	0.16	0.13	0.16	0.16	0.15	0.16
NO_x	Mt	2.82	2.40	2.70	2.77	2.83	2.89	2.04	2.80
CO	Mt	22.00	21.70	19.30	21.90	21.40	18.20	18.80	19.80
HC	Mt	0.59	0.51	0.52	0.56	0.60	0.60	0.40	0.57
CO_2	MtC	736.00	684.00	727.00	725.00	727.00	687.00	591.00	700.00

The chartering of an environmentally sound path for energy production and consumption, requires far-reaching changes in the existing institutional framework. As has been seen in this chapter, an optimal path has been derived under certain assumptions about the economy and the state of technology. In practice, however, such a path may not be achieved because of administrative, legal and financial issues that may be difficult to circumvent. However, the effort should be to move towards an optimal situation in a phased manner.

The BAU scenario constructed here, more or less conformed to the different chains in the fuel cycle possessing the same characteristics as in the past. There were, of course, marginal improvements in the parameters, where these could be brought about almost without cost. The other scenarios constructed, however, have centred around the fact that the BAU scenario alone is not enough to sustain environmentally sound development. Global concerns about climate change have prompted nations to cut down on their level of energy consumption or, to switch over to fuels that have lower emissions. This, of course, does not preclude the fact that fuels which have only local environmental effects are in every way as important as those that have global effects. For this reason, the pattern of energy consumption needs to be changed.

The first scenario which is of energy conservation, points in the direction of reduction in the consumption of fuels. This scenario includes improvements in existing technologies and devices as well as the introduction of lower energy-intensive technologies. Reduction in T & D losses, as well as, substantial efforts towards demand side management have been considered. As a policy move, therefore, this scenario attempts to induce conservation consciousness in the energy producing and consuming sectors and to analyse the impacts thereof. This consciousness can be brought about through enhanced consumer awareness, better housekeeping, and stricter norms for quality by standardizing equipment.

The second and third scenarios are again the result of deliberate policy actions aimed at increased penetration of renewable energy technologies and clean coal technologies. At the moment, the biggest obstacle in the way of the adoption of these technologies is lack of economic feasibility or the high investment costs involved. In order to promote more environmentally benign technologies (renewables and clean coal technologies fall in this category), fiscal incentives for investment have to be given in the nature of low-interest loans (subsidies where necessary), tax holiday for the initial years, allowance for depreciation so that entire capital is recovered in less number of years.

The fourth scenario considers higher development of hydro potential. Several issues like interstate disputes, rehabilitation of displaced people etc., are major constraints in developing hydro potential and need to be resolved.

The fifth scenario which prevents deforestation, needs alternative fuel supply at cheaper price, mainly in rural areas as a substitute for firewood.

On the economic front, efforts should be made to introduce marginal cost pricing (devoid of subsidies), allowing for the liberalization of capital imports, and by inviting the private sector to participate. Legal and trade barriers which have hitherto stood in the way of such technologies need to be removed. On the institutional front, changes have to made in the energy sector to accommodate private participation which alone can help in the promotion of renewable energy technologies. Changes are required in the distribution system especially in the power sector, where private entrepreneurs who are willing to set up wind and solar-power plants, can be given the right to supply power directly. The monopoly of the State agencies in the sale of coal to steel plants is another issue in question, because private coal washeries have no incentive to set up new plants as they are not allowed to negotiate with the consumer directly.

CHAPTER 8

Environmentally sound energy policies and strategies

Energy projections and major environmental impacts

The projected increases in energy demand under the business-as-usual (BAU) scenario, brought out in Chapter 7, are clearly unsustainable. Coal supply would have to be increased from the present levels of about 255 Mt (1992/93) to about 620 Mt in the year, 2011/12. Petroleum product consumption would be more than double in the same period and firewood demand, assuming that supply is not a constraint, would increase from the present estimated levels of 200–250 Mt to about 350 Mt. Given the fact that the sustainable yield of firewood from areas under forests is estimated at about 85 Mt/a, demands of the magnitude indicated would result in a continued degradation of India's remaining forest resources. The nearly three-fold increase in coal demand would place enormous pressures not only on the transportation infrastructure of the country but also on the environment, both local and global. Given that India's coal has an average of about 40% ash, a little over 240 Mt of ash would need to be either disposed of or utilized gainfully which is almost equal to the present day consumption levels of coal.

Electricity generation capacity would have to be increased from about 70 000 MW in 1991/92 to a little over 210 000 MW in 2011/12—an average increase of 7000 MW every year. The share of natural gas would go up significantly and coal would continue to contribute nearly 40% of this capacity.

Acknowledging the fact that these projections of energy demand have been made on the basis of current consumption patterns, which themselves reflect supply-constrained demand, it is quite likely that the actual consumption will be higher than the projections made.

The major environmental concerns arising out of the above pattern of energy development can broadly be classified under the following heads:

Deforestation/resource degradation

Deforestation or degradation of forest resources contributed by the energy sector would take place largely due to hydro development activities, and the continuing stress on forests due to a growing rural population, whose energy needs have not been adequately provided for, through alternative energy forms. The indirect impacts of such a happening would also be felt on soils and water bodies.

Urban environment

The increasing trend towards urbanization and the consequent changes in energy consumption, both in terms of the type and quantity of fuel, combined with the tendency for urban populations to concentrate in larger cities, is already placing urban environments under considerable stress. Urban infrastructural growth is unable to keep pace with the growth in population leading to a breakdown of systems such as water supply, sewerage, roads, solid waste disposal etc..

Ambient air quality

The ambient air quality, which is loaded with emissions from vehicular traffic; domestic energy consumption—particularly the biomass use in urban slums; power generating stations etc. are particularly affected.

Rehabilitation

Rehabilitation issues are gaining importance and are likely to be most prominent in the case of large-scale hydro development projects as well as expansion of the coal mining activities. Given that hydel capacity would have to increase by a factor of nearly three over the study period, it is only to be expected that large segments of population would be affected.

Quality of life

The most important impact of energy developments as they are taking place today can be seen on the quality of life enjoyed (more correctly, suffered), by large segments of the population. In the urban areas, particularly in the large metropolitan cities, the pollutants in the air already far exceed the emission standards prescribed by the Central Pollution Control Board (CPCB). The health impacts of such high levels of pollution, although not very well researched, are estimated to be significant. A recent World Health Organization study had reported that nearly 640 000 children die annually in India due to acute respiratory infections. In rural areas, the continuing dependence on biomass energy is forcing women and children to travel for several hours a day on foot just to collect enough firewood to cook a day's meal.

Transnational impacts

In addition to all the local impacts of energy development, both on population and quality of life, there are significant transnational impacts as well. Transnational, in this context, covers both impacts on a global scale as caused by accumulation of CO_2 due to fossil fuel burning, as well as, more regional impacts such as those caused by emissions of sulphur and nitrous oxides which might result in acid rain.

Alternative energy development paths

India's economic development cannot be constrained. Nearly 25% of India's population continues to live below the poverty line having a per capita average income level of US $256 as compared to a world average of US $4179 in 1991. Targeted economic development can only take place if adequate provision of energy is made. Therefore, what are the options available to meet the energy needs for development? Is it possible to assess the impact of these options on the energy and environment scenario?

There are a large number of options that the country can choose from. Some of these are easily quantifiable, while others are not. The quantifiable options included in the model scenarios described earlier, reflect increased energy efficiencies, acceleration of renewable energy development, introduction of clean coal technologies, increased share of hydro resources and the provision of alternative environmentally friendly energy options for the rural areas. If all of these options were to be successfully adopted, CO_2 emissions would go down by 20% over the BAU scenario and, in the case of a local pollutant, emissions of suspended particulate matter would be reduced by 24% (Figure 8.1). The

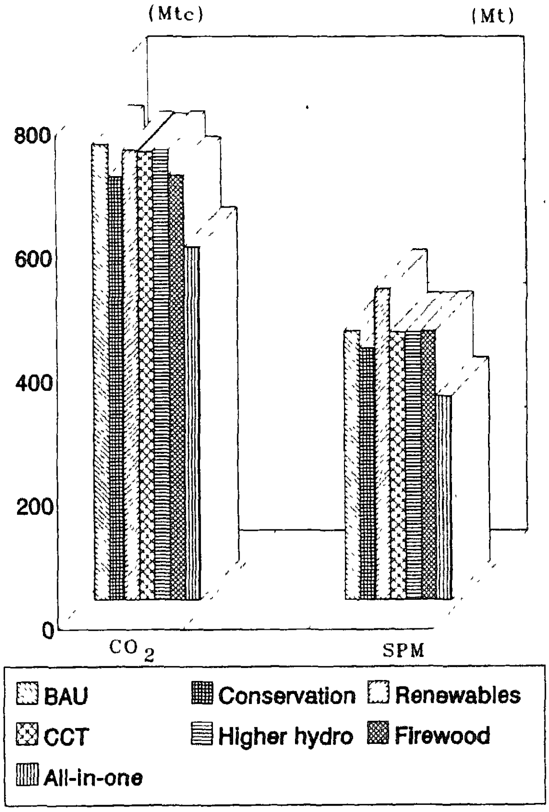


Figure 8.1. Environmental impacts of alternative energy development paths

annuatized energy system costs would change from Rs 4114 billion to Rs 4019 billion. Clearly, adopting the options described would be of great benefit to the country. At the same time, most of the options considered have been spoken about in various expert working group reports on the energy sector brought out since 1965. The fact that we continue to advocate the same prescriptions even 30 years later, points to the fact that little has been achieved so far in converting options into actions. What, in today's situation holds out hope for the future?

Economic reforms: hope for the environment

In the early 1990s, India faced a severe economic crisis brought about largely as a result of low foreign exchange reserves, stagnant growth and large budgetary deficits. As a reaction to this, major economic reforms were undertaken which affected the energy sector considerably.

- There is a declining trend in the budgetary support provided to almost all the energy sectors of the economy, forcing these sectors to look for internal and external budgetary resources to sustain their activity levels. This development has not only forced the energy sectors to bring energy prices more in line with costs, but has also made these sectors more amenable to considering efficiency improvements in other operations.
- Lack of adequate financial resources for capacity expansion in the power sector forced the government to invite private and foreign participation in power generation and distribution. Serious efforts have been made to involve the private sector in other energy activities. As a result, for the first time in decades, the public sector-dominated energy enterprises are facing increasing competition which is sure to have a positive impact on efficiency in the supply sectors.
- In a continuing search for private investment that would enhance energy availability thereby reducing the demand-supply gap, the Ministry of Non-conventional Energy Sources came up with an attractive policy package for bagasse-based cogeneration. In response to this, and on their own initiative, several State Electricity Boards (SEBs) in the country, have offered attractive prices for cogeneration and renewables (wind and micro-hydel) based electricity, which would definitely give a boost to these environmentally benign energy alternatives.
- Continuing the process of reform, several SEBs have provided an enabling environment for the use of existing transmission and distribution (T & D) infrastructure for the *wheeling* of electricity from a private producer to a consumer and also for *banking* of electricity over periods of time. Such

provisions would give a boost to decentralized generation of electricity and would result in overall efficiency improvements.

- Internationally, there exist today several successful experiences with demand side management and integrated resource planning. These have given the domestic energy industry the confidence to consider measures on the demand side as well as against their traditional focus on supply enhancements.
- The Ministry of Environment and Forests has stipulated that, from March, 1992, every industry which comes under the Water and Air Pollution Act, must submit an environmental audit report for each year ending 31st March in the form prescribed under the Rules, to the State Pollution Control Boards. Apart from the statutory requirements under the Air and Water Acts, the Environmental Protection Act, 1986 requires any industry or project to undertake an environmental impact assessment (EIA) which will be reviewed for clearance by the Ministry. The EIA which evaluates the likely economic, environmental and social impact of the project, would form a part of the overall environmental management plan in which impact mitigation measures are suggested/recommended.
- Importantly, international pressure has developed in the last few years reflecting the concern for the build up of greenhouse gases (GHG) as well as the phenomenon of acid rain. These pressures are likely to be more severe in the future when the developing countries would have completed their grace period and would need to identify specific commitments.
- Signifying the concern for climate change, an international financial mechanism, the global environment facility (GEF), has been instituted with the objective of facilitating a transition to more GHG-benign energy technologies and processes.

These developments, both on the domestic and the international fronts, will result in improvements in the efficiency of energy production and use as well as the incorporation of environmental considerations, to a certain extent, in project planning and execution. However, a lot still remains to be accomplished and the next few pages attempt to detail further measures that would have a positive impact on the environment and the policies/strategies that need to be put in place.

Environmentally sound energy practices

The results of adopting some environmentally sound energy options which were easily quantifiable have been considered at the start of this Chapter. In addition, there exist other options, such as the internalization of environmental costs, that, although difficult to quantify with the existing database, would have a positive impact on the environment. The very fact that the measures—both quantifiable and not so easy to quantify—are not adopted widely, points to the need for interventionist (or corrective) policies and measures that would facilitate their adoption.

Integrated resource planning

The focus of energy planning thus far has been on supply enhancements at the producer's end, and that too, in a fragmented manner. Some specific suggestions to plan for meeting the energy demands of the country in an optimal manner include:

- *Natural resource accounting (NRA).* Although a relatively new development, natural resource accounting can provide some very useful insights into the pattern of depletion of a country's natural resource base, including both renewable and non-renewable resources. Applied to the energy resources, NRA can help identify optimal depletion paths by estimating the depletion premia associated with various energy forms, as well as technologies. Recognizing that the technique is far from perfect, it is stressed here that exercises along these lines be initiated in order to understand better, this potentially powerful accounting tool.
- *Greater hydro development.* It has long been recognized that from the point of view of overall system efficiency, hydro power capacity should form at least 40% of the total capacity. This has not been possible so far due to the need to add on lower-cost, smaller-gestation power plants to meet the growing demand for power. However, this situation is likely to change on account of two developments: a larger availability of natural gas-based power generation to meet peaking requirements more efficiently, and the opening up of the power generation sector to private participation. While the former may bring down the norm for hydro-power capacity, private participation should also be encouraged in hydro-power development. As of date, most expressions of interest from private producers have been in the area of thermal (coal or gas) power generation. The two options that the Government has are: Greater incentives to power generation from hydropower and focusing its entire budgetary support for generation capacity expansion on hydropower development instead of thermal power. Needless to say, the environmental costs of hydropower development, including appropriate rehabilitation costs, would have to be built into the project costs.
- *Reduced transmission and distribution losses.* The country, on an average, suffers electricity losses during transmission and distribution of the order of 23%. Significant improvements can take place, particularly, on the distribution side where the losses are classified as *technical* and *commercial.* While the technical losses can be reduced by the measures suggested in Table 8.1, the excuse for commercial losses needs to be removed by reintroducing metered supply of

Table 8.1. Action plan—transmission and distribution loss reduction

Action required	Potential	Impact		Technology implications	Financial requirements	Institutional mechanisms or policy measures
		Energy savings	Environmental benefits			
By installing capacitors at different voltage levels to improve the power factor and reduce losses.	3 per cent reduction in T & D by the year 2006/07	123 240 GWh	1.5 × 10^{11} kg of CO_2 emission reduction	Available domestically	—	a. CEA/Planning Commission should earmark funds for T & D loss reduction b REC could be in charge of implementation. c. Penal measures for SEBs not implementing the policies.
Proper size of transformer so that it is not overloaded	1 per cent reduction by the year 2006/07	41 080 GWh	5.0 × 10^{10} kg of CO_2 emission reduction	- do -	—	
Network to be as low tension as possible.	0 5 per cent reduction by the year 2006/07	20 540 GWh	2.5 × 10^{10} kg of CO_2 emission reduction	- do -	—	
Reorientation of transmission lines as and when required with proper conductor size, preferably Aluminum alloy.	0.5 per cent reduction by the year 2006/07	20 540 GWh	2 5 × 10^{10} kg of CO_2 emission reduction	- do -	—	
Total Reduction in T & D losses, energy loss and environmental benefits	5 per cent (from 23–18%)	2 1 × 10^{11} kWh 38 754 71 MW/tonne of additional capacity saved	2 5 × 10^{11} kg of CO_2 emission reduction	—	Rs 1027 billion	—

Sources

1/ Report of perspective of national power development (2006/07) by CEA

2/ Assuming the energy requirement as per 14th EPS by the year 2006/07

3/ Assuming 1 22 kg of CO_2 reduction per kWh electricity to the agricultural sector and increasing the accountability of the metering and billing divisions.

- *Greater renewable/decentralized energy forms.* The one thing that has not changed significantly in this era of economic reforms, is the attention paid to rural energy requirements and renewable energy options. Whereas some positive developments *vis-a-vis* the renewable energy sector were highlighted in the foregoing section, biomass energy continues to be neglected. Recognizing that biomass energy will continue to play a dominant role in satisfying rural energy demands and that it may not be possible to substitute this energy form entirely by more modern energy forms, it is necessary to develop a well-focussed and well-funded R & D programme that would result in the development and maturing of biomass-based technologies, that are not only more efficient, but less polluting. In order to ensure the success of the programme, it would also be essential to encourage the development of rural entrepreneurs who would ensure appropriate dissemination and servicing of such technologies.
- *Demand side management.* The performance evaluation parameters of the energy sectors have been such that their accomplishment was measured in terms of the quantum of energy produced, and not in terms of the quality or their ability to bridge the demand-supply gaps in the most cost-effective manner. In addition to correcting this anomaly, the Ministry of Power needs to specifically earmark both physical targets for energy savings through demand side management (DSM) programmes, and to allocate sufficient funds for initiating these programmes. Table 8.2 presents some very attractive areas for effecting efficiency improvements through DSM programmes.

Promoting energy efficient appliances and equipment

In addition to all the measures described above that would enable an economically efficient supply of resources—both natural as well as man-made—significant efficiency improvements are possible in the utilization of energy as well. Efficiencies in almost all enduses can easily be increased, from biomass cook-stoves to industrial boilers (Table 8.3 and Table 8.4).

- *Awareness programmes.* Consumer education and publicity programmes would have to be taken up on a concerted basis to make people aware of the potential for energy savings. This is particularly true for the domestic consumers, who can be best reached through the written media or, better still, school-going children, and the small and medium-scale industrial/commercial organizations for whom specific training programmes need to be designed.
- *Rational pricing.* However, the most effective agent of change in this regard would be to have prices that truly reflect the cost of supply of energy, including environmental costs. For this to happen, the setting of prices for energy would necessarily have to:

Table 8.2. Action plan—demand side management

		Impact		Cost of saved energy			
Short term action required (2001/02)	Energy saving in %	Energy savings (MUs)	Environmental benefits (tonnes of CO_2)	Rs/kW	Rs/kWh	Technology implications	Institutional mechanisms or policy measures
Lighting							
Replace 10% existing GLS[a] with CFLs[b] and 10% existing GLS with FTLs[c] Also, replace 10% new GLS with CFLs and 20% new	16 74%	3131	—	—	—	a CFLs are presently being assembled in India b Ballasts are manufactured in India c CFL tube manufacturing has not yet commenced as only production on large scale would prove economical With demand for CFLs, manufacture of the tube can also commence	a MOP to promote DSM along with energy conservation measures to make SEBs responsive to DSM through education, institutional and regulatory reforms b Create Member (Energy Efficiency) post at CEA to assist power planning and similar steps to be taken in SEBs. c. Allocate resources for DSM from plan budget d SEBs to take up demonstration projects and energy audits to bring about awareness of energy efficiency
GLS with FTL	15 53%	708	—	—	—		
Urban domestic	12 41%	2176	3820	—	—		
Rural domestic	—	—	864	—	—		
Commercial	—	—	2655	GLS-CFL 9198 GLS-FTL 3360 GLS-CFL 9198 GLS-FTL 3360 GLS-CFL 10 278 GLS-FTL 2577	GLS-CFL 0 99 GLS-FTL 0 36 GLS-CFL 0 99 GLS-FTL 0 36 GLS-CFL 0 74 GLS-FTL 0 18		
Agriculture							
Improve pump efficiency from 32 4–50%	—	8533	10 410	11 036	0 25	Energy-efficient pumps are manufactured in India, cost of which is 30–40% higher than that of a locally manufactured pump	
Retrofit pumpsets	10 5%	1200	1464	5076	0 12		
Industry							
Rewinding, sizing motors	5 89%	11 049	13 480	10 231	0 38	Energy-efficient motors are manufactured in India and cost about 30% more than a standard motor	
High efficiency motors	0 01%	19	23	15 385	0 57		
	Total	61 08%	26 816	22 900 864			

[a] general lighting system [b] compact fluorescent lamp [c] fluorescent tube light

Table 8.3. Action plan—industry (cement)

Action required	Potential	*Impact*		Technology implications	*Financial requirements*	*Institutional mechanisms or policy measures*
		Energy savings	*Environmental benefits*			
Viability analysis of housekeeping/operational control measures						
Replacement of under loaded motors	Reduction of maximum demand and power consumption by 3–5 per cent		Indirect reduction in CO_2 emissions	Indigenous technology	Minimal	Incentives to the company which consumes electric power below industry norms
Idle running, interlocking *arrangements*	Saving up to 1 per cent of total *power consumption*		- do -	—	Nil	Attitude towards energy efficiency
Preventive maintenance/condition monitoring	Reduction in unscheduled down time *may lead up to 10% energy savings*		Direct/Indirect reduction in CO_2, NO_x and CO		Nil	- do -
Prevention of false air in mills and kiln	Up to 2 *per cent power and 5 per* cent thermal energy savings		*Direct reduction in* CO_2, NO_x and CO	—	Nil	Attitudinal
Minimizing frequent stoppages	Savings up to 2–5 per cent possible		Direct/indirect reduction in CO_2, NO_x and CO emissions	—		- do -
Power factor improvement	Maximum demand and distribution losses reduction		Indirect reduction in CO_2 emissions	Indigenously available	Minimal	Maximum demand costs, power tariff
Load factor improvement	Maximum demand *reduction*		- do -	—	—	- do -
		Total Electricity . 2 0 × 10^8 kWh 34 28 *MW/tonne of energy* saved Coal· 1 61 *Mt*	—	—	—	
Viability analysis of process optimization measures						
Raw mix proportioning	2 per cent fuel, Stable kiln operation, high output, better quality and lower energy conservation		Direct reduction in CO_2, NO_x and CO	No technological implications	Nil	Attitudinal
Coal quality modulation system	Lower energy conservation, higher output		Direct/indirect reduction in CO_2, NO_x and CO	—	Minimal	- do -
Optimum of ball mill charge	3 per cent power, Low energy consumption, higher output		Indirect reduction in CO_2	- do -	Nil	- do -
Material feed system	10% production, 1 5% *fuel*		Direct reduction in CO_2, NO_x and CO	- do -	Nil	- do -
Reduction in primary air	7–8 per cent fuel		- do -	- do -	Nil	- do -
Oxygen enrichment	Up to 10% fuel		Direct/indirect reduction in CO_2, NO_x and CO	No technological implications	Minimal	Attitudinal
Clinker quality maintenance	Up to 12% energy, lower grinding power		Indirect reduction in CO_2	- do -	Nil	- do -

Action required	Potential	Impact		Technology implications	Financial requirements	Institutional mechanisms or policy measures
		Energy savings	Environmental benefits			
Viability analysis of housekeeping/operational control measures						
Chain system optimization	Up to 25% energy, lower thermal power consumption		Direct reduction in CO_2, NO_x and CO	- do -	Nil	- do -
Use of slurry thinners, grinding aids, mineralizers	7–18 per cent fuel, 3–4 per cent power		Direct/Indirect reduction in CO_2, NO_x and CO	- do -	Nil	- do -
Avoiding cement overgrinding	Lower power consumption		Indirect reduction in CO_2	- do -	Nil	- do -
		Total Electricity 2 3 × 10^8 kWh 39 47 MW/tonne of additional capacity saved Coal 2 85 Mt				
Utilization of energy efficient equipment						
Use of high pressure grinding rolls (roller press)	Energy saving of 10–20% and production enhancement up to 40%		- do -	Technology transfer required	Medium term	Maximum demand costs, power tariff
Use of high efficiency classifiers	—		Reduces SPM	- do -	- do -	- do -
Use of multichannel burners	Fuel savings of 2–3 per cent		Direct reduction in CO_2, NO_x and CO emission	- do -	- do -	- do -
Use of high efficiency fans	—		Indirect reduction in CO_2 emission	- do -	- do -	- do -
Use of material conveying systems			Direct/indirect reduction in CO_2, NO_x and CO emission	- do -	- do -	- do -
a mechanical conveying systems	—					
b continuous dense phase pneumatic conveying	Attains 30% more efficiency than the screw pump					
Use of vertical roller mills	Can be used for moisture contents up to 15–20% as compared to 3–4 per cent in ball mills		Indirect reduction in CO_2 emission	Technology transfer required	- do -	- do -
Use of crushers			Indirect reduction in CO_2 emission	Indigenously available	Medium term	Maximum demand costs, power tariff
Use of variable speed drivers			- do -	- do -	- do -	- do -
a Slip power recovery system	Saves up to 30% of power					
b Variable frequency drive	Saves up to 15% of power					
c Variable speed fluid coupling						
Solid state motor controller	—		- do -	- do -	- do -	- do -

Action required	Potential	Impact		Technology implications	Financial requirements	Institutional mechanisms or policy measures
		Energy savings	Environmental benefits			
Viability analysis of housekeeping/operational control measures						
Viability analysis of housekeeping/operational control measures						
Soft starters			- do -	- do -	- do -	- do -
Energy efficient motors			- do -	- do -	- do -	- do -
		Total Electricity 4 6 × 10^8 kWh 78 05 MW/tonne of additional capacity saved Coal 0 48 Mt				
Adoption of new process technologies and production systems						
Use of 5-stage preheater with horizontal cyclones	Savings in thermal energy to the tune of 25–30 kcal/kg		—	- do -	Medium to long term	Energy tariffs
Use of precalcining technology	Approximately, 5% reduction in fuel and 2–2 5% increase in throughput		—	- do -	- do -	- do -
Process conversion	Approximately, Rs 25 crores worth of fuel can be saved annually in addition to increase in capacity by 1 Mt		—	- do -	Long term approximately Rs 300 crores	- do -
Cogeneration	—		—	- do -	Long term approximately Rs 470 crores	Maximum demand costs, power tariff
Utilization of coal and alternate fuels	—		—	- do -	Medium to long term almost Rs 100/t	Energy tariffs
Natural gas	—		—	- do -		- do -
Lignite	—		—	- do -	Medium to long term	- do -
Agricultural waste	—		—	- do -	- do -	- do -
		Total Coal 0 81 Mt				

Table 8.4. Action plan—industry (major energy-saving features of improved steel production)

Action required	Potential	*Impact* *Energy savings*	*Impact* *Environmental benefits*	*Technology implications*	*Financial requirements*	*Institutional mechanisms or policy measures*
Peridur organic bonding process	Significant savings, impact on total operation greater than 200 000 B Th u/t	—	Direct reduction in CO_2, NO_x and CO emission	Technology transfer	Medium to long term	Large capital investments are required to implement these measures
Cold bonding process	Significant savings, impact on total operation greater than 200 000 B Th u/t	—	- do -	- do -	-do-	-do-
Combustion air preheating	Moderate savings, impact on total operation less than 200 000 B Th u/t	—	- do -	Indigenous technology	Medium term Rs 60 lakhs	-do-
Raw materials preheating	Moderate savings, impact on total operation less than 200 000 B Th u/t	2000 GWh	- do -	- do -	Medium term	-do-
Steam or power generation using sinter cooler offgases	Moderate savings, impact on total operation less than 40 000 kcal/t	—	- do -	- do -	Medium term Rs 200 lakhs	-do-
						-do-
Dry quenching	Significant savings, impact on total operation greater than 200 000 B Th u/t	—	- do -	Technology transfer	Medium to long term	-do-
Coke oven gas heat recovery	Significant savings, impact on total operation greater than 60 000 kcal/t	—	- do -	Indigenous technology	-do-	-do-
Top gas pressure recovery	Significant savings, impact on total operation greater than 200 000 B Th u/t	1 GWh	- do -	Technology transfer	Medium to long term $50 million	-do-
Hot stove waste heat recovery, Wurth charging top, improves distribution of ore, coke and limestone	Moderate savings, impact on total operation less than 200 000 B Th u/t	—	- do -	Indigenous technology	Medium to long term	-do-
Discontinued use of open hearth steel furnace	0 9 Gcal/t	(Oil) 40 32 000 Gcal	- do -	Technology transfer	Medium to long term Rs 228 480 lakhs	-do-
In-process control of temperature and carbon content	Significant savings, impact on total operation greater than 200 000 B Th u/t	—	- do -	Technology transfer	Medium to long term	-do-
BOF offgas heat recovery	Moderate savings, impact on total operation less than 0 24 Gcal/t	(Oil) 15 36 000 Gcal	- do -	Indigenous technology	Medium to long term $320 million	-do-

Action required	Potential	Impact		Technology implications	Financial requirements	Institutional mechanisms or policy measures
		Energy savings	*Environmental benefits*			
Combined top and bottom oxygen blowing	Moderate savings, impact on total operation less than 200 000 B Th u/t	—	Direct/Indirect reduction in CO_2, NO_x and CO emission	Indigenous technology	Medium to long term	—
Scrap preheating	Significant savings, impact on total operation greater than 200 000 B Th u/t	2000 GWh	- do -	- do -	Medium term	Large capital investments are required to implement these measures
Ultra high power transformers	Moderate savings, impact on total operation less than 200 000 B Th u/t	12000 GWh	Indirect reduction in CO_2 emission	- do -	Medium to long term	-do-
Bottom tap furnaces	Moderate savings, impact on total operation less than 200 000 B Th u/t	—	- do -	- do -	-do-	-do-
Water cooled furnace panels and top	Moderate savings, impact on total operation less than 200 000 B Th u/t	—	- do -	- do -	-do-	-do-
Ladle metallurgy techniques, including vacuum arc decarburization, argon stirring, and injection systems for desulphurization	Significant savings, impact on total operation greater than 0.6 Gcal/t	NA	- do -	Technology transfer	-do-	-do-
Specialty and stainless steel processes, including electroslag remelting, argon-oxygen decarburization, vacuum induction melting, electron beam melting, and vacuum arc remelting	Significant savings, impact on total operation greater than 0.8 Gcal/t	—	- do -	- do -	-do-	-do-
Ladle drying and preheating	Significant savings, impact on total operation greater than 200 000 B Th u/t	—	- do -	Indigenous technology	Medium term	
Greater use of continuous casting	Significant savings, impact on total operation greater than 200 000 B Th u/t	—	- do -	- do -	Medium to long term	-do-
Modern casters	Significant savings, impact on total operation greater than 200 000 Btu/t	—	- do -	- do -	- do -	-do-
Slab heat recovery	Moderate savings, impact on total operation less than 200 000 B Th u/t	—	Direct reduction in CO_2, NO_x and CO emission	- do -	Medium term	-do-
Soaking pit utilization and pit vacant time	Significant savings, impact on total operation greater than 200 000 B Th u/t	—	- do -	- do -	- do -	-do-

Action required	Potential	Impact		Technology implications	Financial requirements	Institutional mechanisms or policy measures
		Energy savings	Environmental benefits			
Direct rolling of sheet/strip, eliminates needs for reheating of furnace	Significant savings, impact on total operation greater than 200 000 B Th u/t	—	Indirect reduction in CO_2 emission	Technology transfer	- do -	-do-
Reheat furnace waste heat recovery	Moderate savings, impact on total operation less than 200 000 B Th u/t	(Oil) 0 240 Mtoe	Direct reduction in CO_2, NO_x and CO emission	Indigenous technology	Medium term Rs 6000 lakhs	Large capital investments are required to implement these measures
Reheat furnace insulation improvements	Moderate savings, impact on total operation less than 0 3 Gcal/t	—	- do -	- do -	Medium term	-do-
Hot charging of products into reheating furnace	—	—	- do -	- do -	- do -	-do-
Insulated floats for steam savings	Significant savings, impact on total operation greater than 200 000 B Th u/t	—	- do -	- do -	- do -	-do-
Continuous annealing	Moderate savings, impact on total operation less than 200 000 B Th u/t	—	Indirect reduction in CO_2 emission	Technology transfer	- do -	-do-
Batch annealing air preheating	Significant savings, impact on total operation greater than 200 000 B Th u/t	—	Direct/Indirect reduction in CO_2, NO_x and CO emission	- do -	- do -	-do-
Continuous cold rolling	—	—	- do -	- do -	- do -	-do-
Computerized process control Increased combustion efficiency (5% improvement over current practice)	—	Total Electricity—1 6 × 10^{10} kWh, 2770 393 MW per tonne of additional capacity saved Oil—21 67 962 tonnes	- do -	- do -	Medium to long term Rs 10 000 lakhs	-do-

Notes
1/ The investment required in the Iron & Steel sector will be much larger than that indicated in this table because of the fact that the old technologies in the existing plan will have to be replaced
2/ This table also takes into consideration the savings envisaged by the mini steel plants

- be freed from political pressures,
- reflect their resource costs of production/depletion, and
- incorporate the costs of environment protection measures.

While the social necessity of subsidizing select segments of the population is well recognized, the structure of subsidies should be such that they benefit only the selected consumers and minimize the burden on other consumer sectors or energy forms, thereby distorting sectoral balances. Thus, for example, subsidies for the poorer sections of electricity consumers in the domestic sector should be financed through higher costs paid by the larger domestic consumers through the design of appropriate block tariffs and time-of-use tariffs.

A similar approach could conceivably apply to the agricultural sector as well. The benefit of the large subsidy being provided for agricultural electricity consumption is currently going to the larger and medium sized farmers who can afford to pay a much higher price for the electricity that they are consuming. A switch to metered energy supply with increasingly higher prices is sure to have a positive impact on the notoriously low pumpset efficiencies (Table 8.5). A first step in this direction has been taken with 14 states announcing their intention to move to a price of Rs 0.50 per unit for agricultural consumption. But the process of installing meters has to be accelerated. Also, innovative metering arrangements, such as electronic card-operated systems can reduce revenue collection costs and inefficiencies. Political realities would necessitate a slow rise in the prices of metered electricity. The *Panchayat* of a village could possibly be charged with the responsibility of recovering dues from the villagers and a system of offsets against budgetary support devised to minimize the administrative expenses of monitoring and collecting dues from low load areas.

The industrial sector has long been bearing the cost of subsidizing other consumer sectors. While correcting for this, an immediate steep differential between peak and off-peak prices needs to be built-in, for both industrial and commercial consumers that would not only improve efficiencies but also lead to better load management.

- *Energy/environment standard setting and labelling.* While this could be considered as part of an awareness programme, it deserves special mention as it also requires a strengthening of the Indian standard-setting body—the Bureau of Indian Standards (BIS)—to enable them to include energy and environmental considerations as qualifying criteria for their certification process. Particular attention needs to be paid to the large *local* goods market that bypasses the BIS. Labelling of devices indicating their energy efficiencies, combined with appropriate pricing, would enable the consumer to make his choices in a more enlightened manner.

Table 8.5. Action plan—agriculture

Action required	*Potential*	*Energy savings*	*Impact*	*Technology implications*	*Financial requirements*	*Institutional mechanisms/ Policy measures*
Promotion of pumpset retrofits in pumpsets older than 15 yrs	5000 pumpsets every year	43 60 000 kWh 1 069376 MW/tonne of additional capacity saved	Energy savings to the extent of 10% per pumpset retrofitted	Retrofit components available domestically	Rs 475 3243/t of CO	Set up separate agency/ strengthen existing infrastructure
Ensuring energy efficiency of all new pumpset connections	3–5% of total number of pumpsets per year	—	energy savings to the extent of 20% of total consumption	While domestic technology exists, there is scope for technology transfer	—	Above and provide incentives to manufacturers and users
Setting statutory standards for efficient pumpset manufacture	All new pumpsets being manufactured and installed	—	- do -	—		Strengthen testing facilities and producing trained manpower
Providing guidance to farmers on proper operation and maintenance of their pumpsets	Emphasis on all new connections	—	- do -	—	Rs 2037 million	as in (1)
Promoting more efficient irrigation methods and water conservation	- do -	—	- do -	Domestic technology and expertise exists	—	Emphasis on sprinkler and drip irrigation and judicious use of water in surface methods
Establishment of an institutional set-up to handle the above	- do -	—	- do -	—	—	—

- *Enabling Environment.* A switch to more energy-efficient and environmentally benign appliances can be made, provided the consumer has both access to, and information about, the alternatives available. Technological information clearing houses may need to be given a jump- start by providing support for their activities in the initial years of building up their capability. In addition, in the event of new technologies being inducted, the human capacity-building element has to be made a part of the technology acquisition package. The use of economic instruments, such as different taxation, should also be introduced.

  Also, as in the case of the transport sector, more efficient transport options (mass transit systems, compressed natural gas driven vehicles) and infrastructure (adequate good quality road space, railway tracks, compressed natural gas stations) have to be made available before any major efficiency improvements in this sector can be hoped for (Table 8.6). A much greater involvement of the private sector in the building and maintenance of roads is desirable and some efforts are being made in this direction for national highways. The concept needs to be extended for all urban infrastructural facilities, initially perhaps, only for the maintenance of the existing infrastructure.

Clean technologies and energy products

- *Clean Technologies and Processes.* Major incentives in the form of a 100% tax depreciation have been announced in recent years for the installation of pollution control equipment. While the attention being paid to pollution control is desirable, incentive/disincentive structures (pollution taxes), need to be defined that would ensure the operation of such equipment as well. Extending the argument for technological information clearing houses to environmental factors as well, the penalties for violating prescribed environmental standards should be very high. The institutional structures for monitoring and enforcing environmental standards has to be strengthened considerably.

  Recognizing that coal will continue to be the mainstay of the Indian energy scenario, it is imperative that the adoption of cleaner coal technologies—such as the fluidised bed boilers or integrated gasification combined cycle (IGCC) plants, is encouraged actively both in industry and in power generating plants.
- *Cleaner energy products.* The washing of non-coking coal to be moved over distances longer than 1000 km is being made mandatory (Table 8.7). Agreeable as this move is, the reforms process has, by and large, eluded the coal sector. For coal washing to take off on any scale of significance, not only will the private sector have to be invited to set up the coal washeries that are captive to power generating units (present announced policy), but they should be allowed to gainfully utilize the washery rejects and also to market their surpluses at negotiated prices to other industrial consumers. While the consumers of coal will have to pay a larger price for the washed coal, this may be offset,

Table 8.6. Action plan—transport sector

Action	Action required	Potential	Impact		Technology implications	Financial requirements	Institutional mechanisms or policy measures
			Energy savings	*Environmental benefits*			
Introduction of Mass Rapid Transit System (MRTS) in Delhi	Short term—feasibility study and preliminary cost calculation Medium term—detailed design after finalizing the layout and start construction Long term—introduce MRTS operation	Saving on about 1500 BPKm over 35 years, which otherwise had to be met by the road system (saving about 60 million vehicles)	30 Mtoe	14 Mt of CO_2 saved	• Adopt/promote similar technology from MRTS operation in other metropolitan city (Calcutta)	Incremental cost over 35 years • construction and implementation. Rs 8215 9 cr • Operation and maintenance Rs 14 500 cr • electricity generation Rs 800 cr Total—about Rs 23 500 cr Rs 603 96 per tonne of CO_2 saved	Set up institutional body for —operation and maintenance —manpower training —research and development
Increase in share of bus trips in Bombay by 10% during 2000/01	*Short term*—introduce cycle rickshaws or shuttle auto rickshaw services where bus stops/ terminals are far from residential areas, encourage private participation Medium term—provide parking lots inside or near bus terminals for *park and ride* system Long term—multi-level parking structure if required (BOT) set up a transport cooperative	—About 25% reduction in no of vehicles (478) —Cost of construction of parking lots would get recovered from the parking charges over a period of time	—20% reduction in *petrol consumption* —10% increase in diesel consumption 96 000 tonnes of oil equivalent (toe) petrol saved 2000 toe increase in diesel consumption	—50 000 tonnes decrease in CO emission —20 000 tonnes decrease in HC emission	NA	Rs 2000 per tonne of CO_2 saved	Regulatory body for overall coordination

Table 8.7. Action plan–coal

Action required	*Potential*	*Energy savings*	*Environmental benefits*	*Technology implications*	*Financial requirements*
Washery should be an integral part of an opencast coal mine producing inferior grade coal	100 Mt up to 2010–11	Lower transportation costs due to reduction in tonnage to be transported. For TPS[a] alone, located beyond 1000 km, the reductions in tonnage to be moved is estimated at 10 Mt in 2001/02 and 20 Mt in 2001/02	Environmental benefits in TPS[a] like lower quantities of ash to be handled and improved performance of ESPs[b], etc.	Coal washing technology is available within the country	About Rs 20 crores per million tonnes of washery capacity

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[a] thermal power stations [b] electrostatic precipitators

to a very large extent, through the reduced handling costs associated with the high ash in coal, ash disposal costs and improved efficiencies and plant utilization factors.

The move to introduce unleaded petrol in the metropolitan cities is another example of environmental amelioration at source.

Recycling/waste utilization

Recycling is still a nascent industry (in the organized sector) in the country although there exists significant potential for energy generation and savings through this route. Setting right of the energy prices and technological information clearing houses should provide a boost to this industry. In addition, a large number of demonstration projects in various parts of the country would facilitate the generation of interest. Of particular interest, in the present context, would be energy generation from municipal wastes and landfills, and the utilization of ash from power plants. While the former would require wide-scale demonstration effect, the latter would also call for greater R & D input.

International environmental concerns

At present, the major environmental problem of international concern is the emissions of green house gases (GHG). The energy sector contributes to about 60% of the total emission of GHG in the country. A number of the measures listed above would have global environmental benefits as well. However, what has not been tackled is a conscious shift in energy consumption patterns to reflect concern for the global warming phenomenon. What are the options available in this regard?

- *Switch from coal to natural gas.* From a GHG emission point of view, this is a very desirable switch. However, the gas reserves of the country are limited and present production levels are already committed. The option of import of natural gas is being considered seriously, albeit the market for natural gas imports is limited due to the economics involved. An international financing mechanism, such as the GEF, could consider supporting the development of a larger natural gas market by appropriately designed interventions on the consumer's end, based on the principle of incremental costs.
- *Greater penetration of renewables.* This has already been covered in an earlier section. The potential for renewable energy generation in the country is significant (Table 8.8), particularly wind and mini/micro hydel, and the renewable energy programme in these areas, aided by GEF financing, is already underway.

However, considering biomass as a traditional renewable energy form, a lot more needs to be done in this area both in terms of technology R & D as well as the

Table 8.8. Action plan—renewable energy sector

Technology	*Potential*	*Impact*	*Technology implications*	*Financial requirements (Rs*
Biomass	17 000 MW	Efficient use of biomass	More R & D required	1600 billion
Wind	20 000 MW	Strengthening power grid, environmental benefits	Emphasis required on indigenization	1000 billion
Micro hydel	10 000 MW	Rural electrification in remote areas		600 billion
Improved collectors	120 million	Improvement in quality of life, efficient use of biomass	R & D for location-specific designs	1200 billion
Biogas	12 million		R & D in feed materials	[illegible] billion

dissemination infrastructure. Capability building in this area should receive greater attention and possibly be treated as a GHG mitigative measure

- *Transport infrastructure.* Enhancing the carrying capacity of railways and facilitating a switch to compressed natural gas (CNG) as a transport fuel through the establishment of a retail network are infrastructural projects, that would benefit from the leveraging funds possible through the GEF mechanism.
- *Reduced natural gas contributions to GHG.* Natural gas contributes to the accumulation of GHG through the flaring of natural gas Whereas the Government of India plans to eliminate the flaring of natural gas, adequate attention needs to be given to reducing the losses and leakages of natural gas which may account for a fair share of methane build-up.

Institutional strengthening

Governance structures

National level

The National fragmented structure of the energy planning structure and process has resulted in narrow subsectoral targets and suboptimal allocation of resources, geared more towards meeting short-term requirements than planning for a long-term strategy for the sector as a whole. It is essential to correct this anomaly, not through the establishment of a super energy ministry, but possibly through the establishment of a quasi-governmental body comprising the Secretaries of the various energy supply ministries, the Ministry of Environment & Forests, the Planning Commission, representatives of consumer groups, academicians and non-governmental bodies that would not only look at supply enhancements, but would also give due consideration to demand management options, fuel substitution possibilities and environmental impacts. Such a body must be supported by a suitable think tank that performs regular analyses and establishes a strong database and institutional memory on energy and environment issues.

A standing committee, supported by a suitable think tank that would perform regular analyses and establish a strong database on energy and environment issues, needs to be put in place with the following broad mandate:

- ensuring that an integrated, rather than a fragmented view, is taken on energy supply after taking into account the economic, environmental, domestic resource endowment and equity considerations,
- initiating appropriate policy measures to promote efficiency in use of energy and demand side management,
- focusing on, and prioritizing the areas requiring urgent and sustained R & D efforts,and
- evolving guidelines for an energy pricing regime that will promote efficient use of energy and that will also reflect resource costs.

State level

India is a federal country, and the role of the state governments in energy policy and planning has been particularly significant in the area of electricity pricing. Additionally, the state governments have their own system of taxes and subsidies which can be designed to reflect energy and environment considerations at this level.

Lately, the state governments have started evincing a keen interest in policies and actions for the exploitation of the natural resource base in their states, albeit with a greater interest in the royalty earnings that these resources offer.

At the state level too, there exist energy and environmental ministries/departments afflicted with a problem similar to the one at the Centre, namely lack of coordinated planning. The establishment of a Standing Committee as proposed above should be replicated at the state level with broadly the same mandate but obviously tailored to take into account the areas and instruments that fall within the state governments's jurisdiction.

Municipalities/local bodies

A more decentralized form of government exists at the district and city levels. Although not directly responsible for the formulation of any energy/environment policies, the local governments play an important role in assuming the implementation of higher level government policies and programmes in the design of city infrastructure, land use planning, transport planning and management, waste disposal etc.. With the growing sizes of cities, both local infrastructure and urban environments are coming under increasing pressure, which has in itself created an awareness, within the local bodies, of the need to do something different. However, a demonstration programme at the city level of the integrated operation of various options—such as auto time-ups, introduction of part-and-ride schemes, declaration of no-tariff zones, waste recycling and effective utilization, demand management, efficient building designs etc.—combined with a concerted education/awareness programme would considerably boost the introduction of efficient management and operational practices.

Regulatory body on pricing and infrastructure

While the Standing Committee at various levels would suggest and update guidelines for pricing decisions, a regulatory body would need to be set up to ensure adherence to these guidelines to the extent possible, protect consumer interests and facilitate a more optimal utilization of physical and natural resources by mediating interstate transfers/sharing of energy wherever required.

With the increasing role of the private sector in energy production and delivery, the existence of such a body outside the Government becomes almost imperative. The preponderant interest of the public sector in existing energy infrastructure and the need to evolve workable solutions to the sharing of such infrastructure, in order to provide a level playing field, lends urgency to the establishment of such an autonomous regulatory body. The example of the United Kingdom, with energy structures which were very similar to those in India, is a case in point wherein regulatory bodies were established simultaneously with the process of inviting greater private participation in the energy sector.

CASE STUDY I

Energy and environment implications of fertilizer production

Introduction

Indian Farmers Fertilizer Cooperative Ltd. (IFFCO) was established in November 1967, as a multi-unit cooperative organization with the broad objectives of augmenting fertilizer production, ensuring fertilizer availability, and strengthening the cooperative fertilizer distribution system. IFFCO is a federation of over 28 000 societies, most of them being village cooperatives, spread over sixteen states and three union territories. *The organization is distinct in the sense that the farmer owners represented through their village cooperatives also become its customers.*

IFFCO presently owns four giant fertilizer units at Kalol & Kandla in Gujarat State and Phulpur and Aonla in Uttar Pradesh State, having a total annual production capacity of 2.6 Mt of fertilizer material.

The Aonla unit is located about 28 km south-west of Bareilly. The plant with an annual installed capacity of 0.726 Mt of urea was commissioned in a record time of 36 months. The commercial production of urea was started in July 1988 with a capacity utilization of 98% in the first year of its commercial production.

The IFFCO-Aonla unit was selected for this case study because it has adopted state-of-the-art technology for ammonia/urea production; uses natural gas as feedstock; has least energy consumption per tonne of ammonia; and is also equipped with the latest pollution control technologies.

Ammonia plant

Natural gas is used as feedstock as well as fuel in the plant. The gas is supplied by the Gas Authority of India Limited through the Hazira Bijaipur and Jagdishpur pipeline from the South Basin of Bombay High at 40 kg/cm^2. The plant is designed to use a rich mixture but is at present getting only a lean mixture, having a gross calorific value of 8652 kcal/Nm^3 with a sulphur content of less than 4 ppm.

The ammonia plant is based on steam reforming of natural gas using Holder Topsoe (Dutch) technology with an installed capacity of 1350 tonnes per day. The major process steps involved in the production of ammonia are:

- hydrogenation and desulphurization,
- high pressure catalytic reforming (Primary reforming),
- secondary reforming,
- high temperature (HT) shift conversion,

- low temperature (LT) shift conversion,
- CO_2 absorption and stripping,
- methanation, and
- ammonia synthesis.

Hydrogenation and desulphurization

Natural gas at 39 kg/cm^2 mixed with hydrogen (free of CO and CO_2) is preheated to 390°C by a hot flue gas stream of primary reformer and passed over a nickel-molybdenum oxide catalyst in the hydrogenator. All the organic sulphides present in the natural gas are converted to hydrogen sulphide. The temperature is maintained below 400°C, as beyond that, there is a risk of polymerization of unsaturated hydrocarbons. The life of the catalyst is 3–4 years.

The hydrogenated gas at 39 kg/cm^2 and 380–390°C is passed over a zinc oxide catalyst where the hydrogen sulphide and traces of CO are absorbed by the catalyst bed. The gas leaving the desulphurizer is completely free from sulphur. The life of the catalyst is 2–3 years.

High pressure catalytic reforming (Primary reforming)

The sulphur content of the gas entering the primary reformer should not exceed 0.5 ppm. The desulphurized gas at 37 kg/cm^2 and 380°C is mixed with superheated steam for a steam/carbon mole ratio of 3.3:1 and is preheated to 520°C in a process gas plus steam heater using hot flue gases of primary reformer before entering the reformer. In the reformer, the gas and steam mixture is passed through a number of tubes of a catalyst bed (total 288) which are externally heated by side burners (576 burners). The lower catalyst bed consists of pre-reduced nickel and the upper bed has oxidized nickel. Natural gas is let down to 1.5 kg/cm^2, mixed with purge gas and is used as fuel in the reformer. About 5 per cent excess combustion air is supplied along with the fuel mix. Air is preheated to about 247°C by the flue gases from primary reformer in a gas-to-gas heat exchanger. The combustion air blower is driven by a back-pressure steam turbine. The reaction in the reformer is endothermic which partly converts the methane and higher hydrocarbons in the desulphurized gas to CO and hydrogen. The process gases leaving the reformer at 32 kg/cm^2 and 800°C have the following composition:

H_2 — 69.06%
CO — 9.28%
CO_2 — 10.16%
CH_4 — 11.12%
N_2 — 0.37%
Ar — 0.01%

Steam/dry gas mole ratio — 0.713

The flue gases from primary reformer burner side are at 1030°C and the sensible heat is recovered in different heat recovery systems as given in Table 1. The total heat recovered from flue gases amounts to 66.16 Gcal/hr. The flue gases are vented to atmosphere at 150°C.

Table 1. Heat recovery systems in primary reformer flue gas system

	Temperature (°C)		
Heat exchanger	*Outlet flue gas*	*Process steam inlet/outlet*	*Heat duty (gcal/hr)*
Process gas plus steam heater	863	373/520	11.69
Process air heater-I	836	323/550	4 01
HP steam superheater-I	633	361/422	14 01
Natural gas preheater-I	609	304/390	1.94
HP steam superheater-II	424	321/361	14.37
Process air heater-II	388	170/329	2.77
Natural gas preheater-II	321	30/304	4.96
Combustion air preheater	150	47/247	12.41

Secondary reformer

Further reforming of the product gas takes place in a secondary reformer where air is added to provide the nitrogen required for ammonia synthesis. The process gas at 32 kg/cm^2 and 800°C is mixed with air and passed over the catalyst bed. The process air is compressed and preheated to 507°C by primary reformer flue gases before entering the secondary reformer. The catalyst in the secondary reformer is nickel-based on ceramic barrier supported on alumina lumps. The temperature of the combustion zone is 1200°C. The process gas leaving the reformer at 990°C has the following composition:

H_2 — 56.43%
CO — 12.98%
CO_2 — 7.31%
CH_4 — 0.30%
N_2 — 22.71%
Ar — 0.27%
Steam/dry gas mole ratio — 0.526

High temperature (HT) shift conversion

The hot reformed gases at 990°C from secondary reformer are cooled in a waste heat recovery boiler and introduced into a high temperature shift converter at 360°C and 31 kg/cm^2 where most of the carbon monoxide gets converted to carbon dioxide. The catalyst used is iron-chromium. The partially converted gas leaves the HT converter at 450°C and has the following composition:

H_2 — 60.22%

CO — 3.15%
CO_2 — 15.37%
CH_4 — 0.28%
N_2 — 20.73%
Ar — 0.25%
Steam/dry gas mole ratio — 0.394

Low temperature (LT) shift conversion

The gases from the HT converter at 450°C are cooled in the waste heat recovery boiler, trim heater and boiler feedwater preheater to 220°C and introduced into the LT converter. The catalyst consists of chromium base as top bed and copper and zinc as lower bed. The CO slip is 0.25%. The fully converted gases leave the LT converter at 240°C and 29 kg/cm^2 and have the following composition:

H_2 — 61.34%
CO — 0.25%
CO_2 — 17.25%
CH_4 — 0.27%
N_2 — 20.15%
Ar — 0.24%
Steam/dry gas mole ratio — 0.335

CO_2 absorption and stripping

The Benfield process is employed for removal of CO_2 from converted gas. The gas at 29 kg/cm^2 and 240°C is cooled to 110°C in boiler feedwater heaters and the Benfield reboiler. All the steam in the converted gas is condensed, separated and treated in the CO_2 stripper. The condensate stripping removes a substantial part of dissolved ammonia, methane and methanol from the condensate and the condensate is then pumped to the boiler feedwater preparation unit for polishing and reuse as boiler feedwater. The condensate stripper is a packed column containing 28 trays and operates at 0.2–0.4 kg/cm^2 and 90–110°C. LP steam at 3.5 kg/cm^2 and 150°C is used as stripping agent. In the CO_2 stripping section, bulk of the CO_2 in converted gas is removed by absorption, using 30% Benfield solution which has the following composition:

K_2CO_3 — 30.0 %
DEA — 3.0 %
V_2O_5 — 0.5 %

Regeneration of the rich Benfield solution takes place at lower pressures and by supplying additional heat.

Methanation

The very low amounts of CO and CO_2 left after CO_2 stripping are converted to inert methane by passing the decarbonated gas at 340°C over a nickel-based catalyst. The methanated gas at 340°C is cooled to 38°C in the methanator inlet gas heater and by cooling water before entering the compressor. The gases leaving the methanator at 26 kg/cm^2 has the following composition:

H_2	—	74.20%
$CO+CO_2$	—	< 10 ppm
CH_4	—	0.74%
N_2	—	24.76%
Ar	—	0.30%

Syngas compression

Syngas from the methanator is compressed to 212 kg/cm^2 in three stages. About 1850 Nm^3/hr of syngas at 54 kg/cm^2 after first stage compression goes to the desulphurizer.

Ammonia synthesis

The purified, compressed syngas containing N_2 and H_2 in the mole ratio of 1:3 is reacted at about 500°C and 212 kg/cm^2 over an iron oxide catalyst to form ammonia.

Urea plant

There are two streams for urea production in the plant, each having a capacity of 1100 tonnes per day (tpd) based on Snamprogetti (ammonia self-stripping process). Urea is produced by high pressure synthesis of ammonia and carbon dioxide. The production of urea consists of the following major process steps.

- Urea synthesis and high pressure (HP) recovery.
- Medium and low pressure recovery.
- Urea concentration.
- Urea prilling.

Urea synthesis and high pressure recovery

The liquid ammonia is pumped at 200 kg/cm^2 through an ejector which drives the ammonium carbamate from the carbamate separator into the reactor. The carbon dioxide mixed with a small measured quantity of air is compressed in a two-stage compressor to 200 kg/cm^2 and fed to the urea reactor. Ammonium carbamate solution formed is dehydrated in the reactor to form urea and water. The oxygen in the air forms a passive oxide layer on the inner sides of the vessel to prevent corrosion by carbamate and urea solutions. The reaction products from the reactor flow to the HP stripper where the unconverted carbamate is decomposed to ammonia and carbon dioxide. The heat of decomposition of carbamate solution is supplied by medium pressure (MP) steam at 37 kg/cm^2 admitted into the stripper shell. The urea solution thus obtained is pumped to the MP section for further purification. The decomposed vapours from the HP stripper are condensed in an HP condenser to form ammonium carbamate which is pumped to the HP carbamate separator.

Medium and low pressure recovery

Medium pressure section

Urea solution from the HP stripper enters the MP decomposer after pressure reduction through a level control valve during which most of the remaining carbamate decomposes to ammonia and carbon dioxide, thereby increasing the concentration of the urea solution. The urea solution further goes to the LP decomposer. The vapours from the MP decomposer are condensed in an MP condenser using carbamate solution from the LP section to form ammonium carbamate. The carbamate solution from the MP condenser goes to an MP absorber where the excess ammonia, inerts and a little CO_2 are separated and purified ammonia is condensed and collected for recirculation

Low pressure (LP) section

The urea solution from the MP decomposer is expanded wherein most of the remaining carbamate solution decomposes. The concentrated urea solution flows to evaporators for further purification. The decomposed vapours from the LP section are absorbed in aqueous carbamate solution in the LP condenser from which it is pumped to the storage tank for use in the MP condenser.

Urea concentration

The urea solution from the LP decomposer is concentrated in a two stage evaporation system operating at 0.3 and 0.03 kg/cm^2 to 72% and 99.8%.

Urea prilling

The 99.8% urea solution from the evaporators is pumped to the top of the prilling tower and sprayed by using a rotating prill bucket. The fine droplets of the solution, while descending through the tower, come in contact with the cold air and solidify to form prills. Urea prills from the bottom of the prill tower are sent to the urea silo or product handling plants.

Steam and Power Generation Plant

A steam and power generation plant has been provided to maintain regular and uninterrupted supply of steam and power to the process plants. There are two gas turbine generators, each having a generation capacity of 18 MW. The gas turbines are equipped with two heat recovery steam generators each of 80 tph capacity to recover the heat from flue gases. The steam generation plant (SGP) using natural gas as fuel has a capacity to generate 150 tph of steam at 117 kg/cm^2 pressure and 515°C temperature. SGP also has a provision to use low sulphur heavy stock (LSHS) as fuel if the need arises.

Energy consumption

The energy consumption of ammonia and urea plants is given (Table 2 and Table 3).

Table 2. Specific energy consumption per tonne of ammonia

Energy	*Guaranteed*	*Actual (1992/93)*	*Average for gas based plant*
Fuel + feed (Gcal)	7.780	7.738	–
Electrical (kWh)	29.510	30.010	–
Overall (Gcal)	7 809	7.808	9 48

Table 3. Specific energy consumption per tonne of urea

Energy	*Guaranteed*	*Actual*
Ammonia (tonne)	0.574	0.580
Electrical (kWh)	65.930	55.010
Steam (tonne)	1.070	1.208
Overall (Gcal)	9.947	10.194

As can be seen from Table 2, the energy consumption of the ammonia plant is very close to the guaranteed figure. The average energy consumption per tonne of ammonia for all gas based plants during 1992/93 is 9.48 Gcal, and the IFFCO-Aonla plant has achieved the lowest energy consumption figure of 7.808 Gcal. The actual energy consumption per tonne of urea is higher by 0.2 Gcal than the guaranteed consumption.

A time series data on energy consumption of the Aonla unit per tonne of ammonia is given in Table 4. As can be seen from the table, the specific energy consumption per tonne of ammonia has steadily come down with increased capacity utilization. Various energy conservation measures as given in Table 5 also helped in reducing the energy consumption of the plant.

Energy conservation measures adopted

Energy conservation at IFFCO, Aonla unit has been an integral part of the management philosophy as well as the operational process. In keeping with the goal of optimizing the use of energy, the management has been aiming for significant reduction in energy

Table 4. Specific energy consumption of ammonia plant

Year	*Gcal/t ammonia*	*Capacity utilization*
1988/89	8.21	66.8
1989/90	8.01	106.2
1990/91	7.83	116.6
1991/92	7.92	109.7
1992/93	7 81	108.5

consumption to be brought about by various energy conservation measures implemented. Some of the major measures undertaken by the plant along with the investment involved and the savings achieved are given in Table 5.

Table 5. Energy conservation measures adopted

	Savings		
Energy conservation measure	*Gcal per hr*	*Rs (million/year)*	*Investment Rs (million)*
Use of electric drive in place of steam turbine for cooling water pump	5.80	12.50	Nil
Recovery of CO_2 from compressor seal leaks by installing an ejector	2 02	4 50	1.13
Installation of combustion air preheater	1 18	2 60	2.50
Recovery of ammoniacal water from interstage separator	0 94	0.21	0 30
Utilization of boiler blowdown	—	—	0.01
Alum dosing by gravity	—	0.002	—
Replacement of pump with ejector for sulphuric acid dosing	—	0 05	—
Modification of piping layout of chlorine dosing system	—	0 1	0.4
Replacement of PGL speed controller with the modified PGPL governor for boiler feedwater pump	—	—	1 6

Energy conservation—Future plan

- Use of MP steam (37 kg/cm^2) in urea hydrolyzer in place of HP steam during 1994/95. The total investment requirement will be Rs 1.6 million.
- Installation of MP stripper in place of LP condensate stripper in ammonia plant and recycling of the trace impurities along with steam to primary reformer. The savings envisaged are 0.06 Gcal per tonne of ammonia and the investment is about Rs 70 million.

Environmental management

The policy of the company is a systematic approach towards total environmental management which includes pollution abatement at source; water conservation and adequate treatment technology; safe disposal of waste and monitoring of ambient air quality, river water quality, treated effluent quality and constant interaction for its betterment.

Salient features of the plant

- Recycling and reuse of waste water to achieve **zero effluent discharge** from ammonia and urea plants.
- Centralized effluent treatment plant (CETP) for treating cooling tower blowdown and occasional wastes from plants.
- 80 metres wide green belt around the factory and maximum utilization of treated waste for the development of the green belt.
- Afforestation in township and treated effluent lagoon.
- Effective operation/maintenance of in-built safeguards and monitoring devices.
- Creating awareness among factory employees regarding environmental quality.

Water pollution

Sources of waste water

Water is used in the plant for cooling, steam generation, injection into the processes and air pollution control devices. The total water requirements of ammonia are 230–780 m^3/t and of urea 80–370 m^3/t.

- Process waste water originating primarily from condensation of vapour exhaust streams.
- Ammonia contaminated cooling tower water due to leaks and stack vents.
- Cooling tower, boiler and compressor blowdown.
- Compressor blowdown contains high concentrations of oil and greases generated from syngas and process air compressors.
- Regeneration of solutions from ion exchange systems normally used to provide feedwater.
- Waste water from wet scrubber and other air pollution control devices.
- Sanitary waste water.
- Non-point sources such as accidental spills, valve and pump-seal leaks, overflows, plant washdowns and storm runoff.

Characteristics of waste water

- Principal contaminants are ammonia nitrogen, nitrate nitrogen, organic nitrogen, and suspended solids.
- Chromates and phosphates show up in cooling tower and boiler blowdown effluents respectively.

- Ammonia is found in process condensates and also in storm waters as a result of absorption during periods of precipitation.
- The process condensate from ammonia plant will contain methanol (1000 mg/litre), methylamine, diethylamine and trimethylamine (all around 20 mg/litre) plus small amounts of iron, copper, zinc, sodium, calcium and aluminium.
- Organic nitrogen comes mainly from the urea plant. The manufacturing process, however, provides for recycling of unreacted ammonia.

Zero effluent discharge concept

The plant has adopted the following methods for achieving zero effluent:

Process condensate stripper

The contaminated process condensate stripping is carried out in CO_2 and condensate strippers with LP steam. After stripping off the impurities like CO_2, ammonia and methanol, the stripped condensate is further treated in a polishing unit before recycling as boiler feedwater. The gaseous overhead product is condensed in the overhead condenser for recycling as reflux and a part is reused in the reforming section.

Turbine condensate polishing unit

This is used for the recycling of process and turbine condensates. Turbine condensate is contaminated with a small quantity of dissolved and undissolved solids. It is treated in the condensate polishing unit of the ammonia plant. The polishing unit comprises an activated carbon filter to remove organic and undissolved matter and a mixed bed unit to remove dissolved solids.

Reuse of boiler blowdown

The boiler blowdown is flashed in a vessel to generate saturated LP steam of 21 tpd at 4 kg/cm^2 and fed to the LP steam header. The remaining blowdown condensate (39 tpd) is used as cooling tower make-up.

Waste water treatment system

Treatment of urea bearing waste water

The urea bearing waste water containing 0.98% urea and 4.76% ammonia is treated in a deep urea hydrolyzer with 37 kg/cm^2 steam, recovering CO_2 and ammonia. The recovered materials are condensed and reused. The treated water is used as cooling tower make-up or boiler feedwater.

Oil separation

The spilled oil in the plant is led through underground PVC pipes to an oily-water basin. Oil and water form two phases with the oily layer at the top. The oil is skimmed off in the oily-water disc unit of a disc oil-separator, and transferred to a slop-oil tank. Oil is collected from the tank in drums and disposed. The waste water from the slop-oil basin is pumped to the neutralization pit.

Neutralization of acidic and alkaline waste water

Alkaline and acidic waste water are generated during regeneration of ion exchangers. To neutralize these wastes, the plant has neutralization and pumping facilities. Both the neutralization pits of ammonia and water treatment plants are connected to centralized effluent treatment plants.

Centralized effluent treatment plant (CETP)

Floor washing/spillage/occasional wastes from urea, and ammonia plants are collected in an effluent collection pit for further treatment in CETP. Ammonia and urea plants have separate cooling towers which use chromate-based corrosion inhibitors. The chromated cooling tower blowdown water is treated in CETP. The capacity of the treatment plant is 250 m^3/hr.

Effluent disposal

The treated effluent is sent to effluent lagoons/guard ponds. There are two guard ponds at the terminal end, each having a holding capacity of 85 000 m^3. These ponds are double lined with PVC and low density polyethylene (LDPE) sheets to prevent groundwater contamination. The analysis of the treated effluent carried out in the plant and the corresponding standards is given in Table 6.

Table 6. Treated effluent analysis

Parameter	*Actual value*	*MINAS value*
pH	7 91	6–8 5
Ammoniacal nitrogen	11.69	50
Free ammonia	1.33	5
Total nitrogen	17.95	1
Hexavalent chromium	traces	0 1
Oil and grease	traces	10

Air pollution

Emission sources

- Major emissions from the plant are ammonia, particulates from prill towers, granulators, dryers, screens, coolers and evaporators; and NO_x resulting from different operating practices and certain processes.

- SO_x, NO_x, CO, particulates and hydrocarbons emitted from primary reformer where natural gas and purge gases are fired.
- During regeneration of CO_2 scrubbing solution (Benfield solution), smaller amounts of water vapour, ammonia (1.0 kg), CO (1.0 kg) and methane (<0.75 kg) per tonne of ammonia are generated.
- Purge gas containing 62% hydrogen, 21% nitrogen, 4 per cent argon, 11% methane and 2 per cent ammonia is used as fuel in the primary reformer along with natural gas.
- Prill tower emissions result from the carryover of fine particles and fumes by the air exiting the tower. Increased air velocity in the tower increases the entrainment of particles.
- Sources of fugitive ammonia emissions are: storage tanks and their pressure relief valves, ammonia compressors, spills during loading and pumps.

Air pollution prevention and control measures

Efficient combustion control to prevent pollution

- The sulphur content in natural gas is negligible. However, the unit has SO_2 and NO_x analyzers as in-built monitoring tools in flue gas stacks of ammonia, as well as, steam and power generation plants.
- CO and O_2 analyzers are also incorporated in the furnaces to ensure efficient combustion and to reduce pollution.
- Alternate fuels like fuel oil/LSHS with higher sulphur contents are also used sometimes in boilers. The stack height of the boiler is 120 m to ensure efficient plume dispersion.
- The problem of H_2S and SO_2 emissions has been eliminated by using ZnO in place of activated carbon. The spent bed is disposed of after 1 or 2 years by landfilling.

Dedusting system at urea prilling tower

- The water jet scrubber system controls urea dust emissions from the natural draft prilling tower. The circulating urea solution with about 10% urea concentration is drawn for recycling and reuse.

The ambient air quality of the plant and the standards are given in Table 7.

Solid pollution

Solid waste sources and their characteristics

- Zinc oxide beds used for desulphurization of feed gas are disposed of by landfilling.

Table 7. Ambient air quality (μ gm per Nm^3)

Parameters	Actual value	MINAS value
Sulphur dioxide	traces	80
Nitrogen oxides	17.1	100
Ammonia	50.5	—
Carbon monoxide	traces	—
Suspended particulates	130.1	200

- Spent catalyst must be replaced as per requirements. The catalyst beds such as nickel, cobalt, molybdenum, oxides of chromium, iron, copper and zinc are disposed off by landfilling.
- The sludge containing the suspended and dissolved solids such as carbonates, bicarbonates, hydroxides, silica, etc. from the bottom of the clarifier is sent to ponds or landfill site.
- Generally there is no solid waste generation in a urea plant. Any fines or spills are recycled in the process.

Different pollution control equipments installed at IFFCO-Aonla plant to minimize the water, air and solid pollution are given in Table 8.

Table 8. Pollution control equipments at IFFCO-Aonla plant

Pollution control device	Designers/ suppliers	Capacity (m^3/hr)	Pollutants	Concentration	
				Inlet	Outlet
Process condensate stripper	Halder Topsoe, Pdil, G R Engg	95	Ammonia	500 ppm	5 ppm
			CO_2	900 ppm	traces
Turbine condensate polishers	Ion Exchange	150	Dissolved solids	12 μ-mho	< 0.1 μ-mho
Disc-oil separator	Brevetti O C S	15	Oil	—	< 10 ppm
Urea hydrolyzer	Snamprogetti, Kaveri Engg	60	Ammonia	4.76%	25 ppm
			urea	0.98%	10 ppm
Neutralization pits					
ammonia plant	Ion Exchange,	150 m^3	Acidic &	4–10	7–8.5
water treatment plant	DCPL	500 m^3	alkaline	—	—
CETP for					
chromate removal	DCPL/	480	CrO_4	30 ppm	0.1 ppm
air stripping unit	Enviro Control Associates	60	Ammonia	500 ppm	25.0 ppm
Dedusting system	E A Wiegand	1 250 000*	Urea dust	40 mg/Nm^3	30 mg/Nm^3

*in Nm^3/hr

Environmental management practices at Aonla plant

Environmental management laboratory

The plant has a full-fledged laboratory to monitor and analyse the ambient air for SPM, ammonia, SO_2, NO_x and CO, and water qualities. A wind monitoring station is also operational at the site. For monitoring the treated effluent going to the Aril river, one continuous sampler is installed in the lagoon discharge channel. River water analysis is also carried out before and after the point of confluence of effluents to assess the effect of the effluent discharged into the river.

Green belt development

- The land selected for the project was a barren tract with high alkalinity. An 80 m wide green belt has been developed and additional afforestation is in progress. About 150 000 trees have been planted using pyrite treatment methodology along with gypsum, sweet soil and cowdung manure.
- To boost the social forestry scheme surrounding the plant, the unit distributes free saplings to villagers from its social forestry farm.

Fire and safety aspects. A fire and safety department was also established along with the main plants, keeping in mind, the safety of personnel and machinery in addition to the several safety features in the design of the plant.

The fire and safety department is equipped with sophisticated and modern facilities like fire fighting tenders, fireproof clothing, safety belts, gas marks, explosive meters, etc. Various safety competitions and seminars are arranged from time to time to increase the awareness for adopting the safe practices. A detailed disaster management plan has also been prepared to deal with any unforeseen occurrences.

Awards and recognition

IFFCO has earned several awards for their performance in the production and productivity, project implementation and safety. The recognition came from various prestigious organizations like the Fertilizer Association of India, National Productivity Council, National Safety Council (Bombay and USA), Institute of Chartered Accountants of India, Government of India, Federation of Indian Chambers of Commerce and Industry.

Conclusion

The plant has state-of-the-art technology using natural gas as feedstock as well as fuel. It uses the latest energy-efficient and pollution control equipments. Improvement of energy efficiency has been an integral part of the operation by adopting various energy conservation measures. The salient features with regard to energy efficiency and environment are summarized.

Energy efficiency

- The energy consumption of the Aonla plant is one of the lowest among the gas-based plants in India. The capacity utilization of the plant has remained above 106% since 1989/90.

- The average energy consumption per tonne of ammonia for all gas-based plants during 1992/93 is 9.48 Gcal and for IFFCO-Aonla plant, the value is 7.808 Gcal.
- The plant has installed the latest electronic monitoring/control systems to maintain close control on critical process parameters.
- The technology adopted by the plant has in-built waste heat recovery systems in various process sections to maximize the energy use efficiency.
- In keeping with the goal of optimizing energy use, the management has implemented various energy conservation measures like use of electric drive in place of steam turbine for the cooling water pump and recovery of CO_2 from compressor seal leaks by installing an ejector. This is reflected in the overall energy consumption of the plant.

Environment

The plant has adopted a systematic approach towards total environmental management

- Waste water generated from various processes of the plant is recycled to achieve zero effluent discharge.
- Cooling tower blowdown and occasional waste water from the plant are treated in a centralized effluent treatment plant.
- Various in-built safeguards and monitoring devices have been installed for effective operation/maintenance of the plant.
- The plant has installed various pollution monitoring and control equipments to keep the pollution within limits.
- The plant has developed an 80 metres wide green belt around the factory by effectively utilizing the treated wastes.
- The plant has two effluent lagoons which are double lined with PVC and LDPE sheets to prevent groundwater contamination. This treated water is used for afforestation in the township.

Potential environmental impacts and mitigative measures are given in Table 9.

Table 9. Potential environmental impacts and mitigative measures

Potential negative impacts	*Mitigating measures*
Site selection	
Siting of plant on/near sensitive habitats such as mangroves, estuaries, wetland, coral reefs	Site selection has taken care of these problems.
Siting along water courses causing their eventual degradation	Liquid effluents generated are sufficiently treated and recycled to have zero effluent discharge thus preventing any degradation of water courses near the site.
Siting can cause serious air pollution problems for local area	Sufficient stack height (120 metres) has been provided for efficient plume dispersion avoiding localized concentration of air pollutants at ground level.
Siting can aggravate solid waste problems	Sufficient land has been provided to dispose of the solid wastes generated in the plant by landfilling. The problem of H_2S and SO_2 emissions is eliminated using ZnO catalyst in place of activated carbon.
Plant operation	
Water pollution from discharge of liquid effluents and process cooling water or runoff from waste piles	Waste water from various process centres is recycled and reused to achieve zero effluent discharge. Cooling tower blowdown and occasional waste water are treated in centralized effluent treatment plant. Treated effluent is sent to effluent lagoons
Ammonia, urea, COD and pH	Zero effluent discharge. pH level is maintained between 7 and 9.
Particulate emissions to the atmosphere from all plant operations	Water jet scrubber has been installed to limit urea dust emissions from prilling tower Natural gas with traces (<4 ppm) of sulphur is used as fuel and feedstock.
Gaseous emissions of SO_x, NO_x and ammonia to the atmosphere	SO_x & NO_x in-built monitors are provided in flue gas stacks. CO and O_2 analyzers in boilers ensure efficient combustion to reduce pollution. For efficient plume dispersion due to occasional firing of FO/LSHS with higher sulphur content by providing higher stack height (120 metres). The problem of H_2S and SO_2 emissions is eliminated using ZnO catalyst in place of activated carbon.
Accidental release of potentially hazardous solvents, acidic and alkaline material	Adequate storage facilities have been provided for ammonia, sulphuric acid and CO_2.
Surface runoff of constituents, raw materials and solid wastes frequently stored in piles on the facility grounds can pollute surface water or percolate to ground water	Feedstock and fuel i.e. natural gas, come by pipeline. There are storage tanks for FO/LSHS. Intermediate products such as ammonia, CO_2 and ammonium carbamate also have storage facilities.
Occupational health effects on workers due to fugitive dust, material handling or other process operations and accidents occur at higher than normal frequency because of labour skill level	The plant has a safety and health programme designed to identify, evaluate, monitor and control safety and health hazards. address the hazards to worker health and safety. provide safety training propose procedure for employee protection.
Regional solid waste problem exacerbated by inadequate on-site storage or lack of ultimate disposal facility	Adequate on-site disposal has been provided.

Potential negative impacts	*Mitigating measures*
Transit patterns disrupted, noise and congestion created and pedestrian hazards aggravated by heavy trucks transporting raw materials to/from facility	Site selection has taken care of the congestion and noise pollution. Natural gas supply is by pipelines FO/LSHS come by trucks.
Increasing nitrate pollution of ground water from use of nitrogenous fertilizers	The solid wastes generated, such as spent catalysts and sludge from clarifiers, are disposed of by landfilling.
Eutrophication of natural water systems	The effluent lagoons are lined with PVC and LDPE sheets to prevent ground water contamination

CASE STUDY II

A Model for optimizing urban systems in their environment (MOUSE)

A case study for Delhi

Introduction

One of the foremost concerns in India is the deterioration of air quality, particularly in the urban areas. The need for incorporating these considerations into the planning framework has been recognized and initiated. Despite increasing environmental awareness and improved data gathering, such tools are yet to be used in land use planning.

Rationale

Over the past three decades, Delhi has witnessed rapid urbanization and industrialization. Delhi records the highest total air pollution load of 871.92 tonnes/day as compared to other metropolitan cities. The motor vehicle population in Delhi is 2.05 million and is greater than the vehicles in Madras, Bombay and Calcutta taken together. Delhi, with a population of over 8.3 million in 1991, records 12 times the national average for respiratory ailments mainly due to unchecked pollution. Hence, Delhi was chosen for conducting a case study on urban energy and environmental planning.

Delhi—a profile

Delhi is the capital city of India and is a rapidly expanding centre of government, trade, commerce and industry. This city is a major transport hub and has a high motor vehicle population compared with other Indian cities. The city is situated between the Thar Desert of Rajasthan to the west; the central hot plains to the south; and the cooler, hilly region to the north and east. A regular pre-monsoon feature are the dust storms prior to June, where Westerly winds from the Great Indian Desert deposit large concentrations of suspended particulate matter (SPM) into Delhi's atmosphere. Alternatively, premonsoon calms—which occur as frequently as 20% of the time—often lead to increased pollution loads due to lack of mixing/dilution. Thus, the suspension and resuspension of natural dust is one of the foremost concerns in Delhi.

Delhi's population stood at 8.3 million as at the end of 1991 and is projected to increase to 12.77 million in the year 2000 (UN). Rural-urban and inter-urban migration are the main reasons for Delhi's population growth. Though Delhi is typically a *service town*, industry is rapidly increasing despite the introduction of planning restrictions on large industry. Delhi has two major thermal power plants—Badarpur and Indraprastha. The degree of pollution attributed to Delhi's power plants is a cause for concern with the growing incidence of tuberculosis in workers at the plant site at Indraprastha. High levels of SPM are believed to be an important co-factor. In Delhi, the mass transport facilities are inadequate, although the establishment of a ring railway and ring bus service have helped mitigate part of the overall problem.

Objectives of the study

The objective of the proposed study was to develop an evaluation framework, and a computerized decision support system for urban energy and environmental planning. The aim was to study the impact and implications of energy on the air quality in Delhi. This software would allow the decision-makers to study the impact of alternative strategies on total energy consumption and the resulting emissions. This model has been run using data for the city of Delhi (as one grid). However, the model could be applied to any typical urban agglomeration.

The specific activities of the study are:

- to estimate the energy consumption by sector (domestic, commercial, industrial, power generation, transportation) and by energy source (coal, kerosene, diesel, gasoline, fuel oil, firewood, LPG, electricity, etc.),
- to estimate the emissions of different pollutants (SPM, CO, HC, NO_x, SO_2, Pb) due to energy production and consumption in the city of Delhi from various sources,
- to develop models to predict the concentration of various pollutants resulting from various sources,
- to evaluate various technologies—their effect on the energy consumption and air pollution levels—and to identify the cost-effective options, and
- identifying options and assisting in choosing viable alternatives, which would set the pace for environmentally compatible energy development.

Framework for analysis

In the present study, Decision Support Systems (DSS) has been structured into four modules. They are:

- energy balance module,
- environmental pollution balance module,
- technology and costing module, and
- decision support module.

A brief description of the activities follows:

Pattern of urban energy consumption

Before exploring the specific energy-environment interactions, it is necessary to understand the overall structure of urban fuel use. The sectors to be analysed will include domestic, transport, industry and commercial. Each sector will be considered separately. The linkages between them will be analysed through the use of the DSS system. The following are some of the factors which will be considered for the various sectors being included.

Domestic

Analysis of energy use by:

- fuel type: LPG, kerosene, firewood, softcoke, dung-cake, electricity, etc.,
- enduse: cooking, water heating, space heating, cooling and lighting, and
- income levels: I , II , III and IV .

The basis for any estimate or analysis of household energy use is the household energy survey for Delhi. Projections of energy demand for 1996/97 are based on the estimated population distribution across income levels, assuming no change in the annual per capita consumption.

Transportation

Analysis of energy use is by

- mode: Passenger
  Freight

The energy demand by mode for 1996/97 is based on the growth rate of the vehicles projected for Delhi. It is assumed that the annual utilization remains the same in the short run.

Industry

The energy demand by type of industry is based on the growth rate of these industries. It is assumed that in the time frame under consideration, there would be no major changes in the technologies used by the industry.

Commercial sector

A wide variety of energy consuming activities characterize this sector. However, this study focuses only on lighting for want of data.

Environmental implications of energy production, transformation and consumption

The air pollution in a region depends upon pollution source characteristics, and the ability of the atmosphere to disperse, and dilute pollution loads generated by energy related activities. The capacity of an air basin over a region to perform this depends upon a variety of factors, including the amount and type of pollutants emitted and meteorological and topographical characteristics of the region. To examine the air quality in Delhi, the following methodology is being adopted:

Source inventory

Sources are generally referred to as point, line, and area sources. Point sources represent major identifiable sources within a region, such as power plants. Line sources represent emissions from motor vehicles along the major corridors. Area sources represent a cluster of small industrial sources, domestic emissions etc. The point, line and area sources will be mapped in the study area.

Estimation of emissions from different categories of sources

. Pollution source characteristics include the quality of emission and the physical location and configuration of the sources. The principal pollutants of concern are (SO_2), (NO_x), (CO), (HCs), (Pb) and SPM. The emission inventory will be divided into source categories: household and commercial sector, transport, industry and power.

Development of an air pollution balance

Based on the sectoral emissions at the disaggregate level, a comprehensive air pollution balance will be prepared. At this stage, it will be possible to desegregate physical quantities of different energy related emissions by their sources in order to understand the structure of pollution, and to identify possible intervention points.

Use of air pollution dispersion models

To estimate the desired reduction of pollution or to define the tolerance levels of a geographical area for receiving additional pollution from further development, it is essential to translate emissions from different sources into pollution concentrations in a given area. The ambient concentration of pollutants at the ground level, is an important indicator of the level of pollution. Such a concentration of pollutants not only depends on the rate of emissions but also on the meteorological variables such as wind speed, stability conditions, mixing height etc. Concentration of pollutants at any place and time can be known either by direct monitoring or by modelling.

There are several urban diffusion models to determine space and time variations of pollutants and of these, the source-oriented model, receptor oriented model, statistical model, tabulation prediction scheme, and numerical technique, deserve mention. Each technique has its own advantages and limitations. Out of these, the source oriented model is less time-consuming and easy to handle for land use and planning purposes. The model helps in predicting the concentration of pollutants for point, line and area sources for a given input of meteorological parameters and source emissions.

The meteorological parameters pertinent to the problem of air pollution such as seasonal wind speed and direction, atmospheric stability, mixing height etc. have been augmented by collecting recent information from the Indian meteorological department (IMD), New Delhi.

Air quality status in the National Capital Region

The Central Pollution Control Board (CPCB), under the programme National Ambient Air Quality Monitoring (NAAQM) has monitored the emissions of and suspended particulate matter. In Delhi, there are six NAAQM locations. They are at Ashok Vihar, Janakpuri, Nizamuddin, Shahdara, Shahzada Bagh and Siri Fort. The annual and 24-hourly mean values for sulphur dioxide and nitrogen dioxide did not exceed the stipulated standards during 1990/91. The 98-percentile values for SPM exceeded the prescribed standard during the year 1990/91.

Hence, a background concentration of 40 micrograms of SO_2, 50 micrograms of NO_2, 3500 micrograms of CO and 500 micrograms of SPM are to be added to the incremental concentrations from energy-related activities. No background concentrations have been assumed for HCs and Pb.

CPCB laid down air quality standards in the year 1982. The standards are different for the type of geographical area. The concentrations for the prescribed pollutants should be within the prescribed limits, 95% of the time as given in Table 1 below.

Table 1. Ambient air quality standards (micrograms per cubic metre)

Category	*SPM*	*SO_2*	*CO^2*	*NO_2*
Industrial and mixed area	500	120	5000	120
Residential and rural	200	80	2000	80
Sensitive	100	30	1000	30

Identification and costing of alternatives

Though there exist many technological options for mitigating or partially solving energy-based urban environmental problems, the crux of the problem lies in identifying viable alternatives.

The first scenario includes both energy conservation measures and technological upgradation in the power, industry, domestic and transport sectors. It is assumed that for the chosen technologies, 50% of the existing ones would be replaced by energy-efficient technologies. The technologies chosen for replacement/upgradation include: kerosene and LPG stoves in the domestic sector, boilers in the industry and power sectors, and 2-wheelers, buses, cars, and trucks in the transport sector. In addition, this scenario takes into consideration, the replacement or upgradation of efficient electrical appliances/equipment, and thus, the reduction in the demand for power is incorporated to arrive at the resulting emissions from the power sector.

Air quality prediction for Delhi

To estimate the desired reduction of pollution, or to define the tolerance levels of a geographical area for receiving additional pollution from new developments, it is essential to translate pollution emissions from different sources into pollution concentrations in a given area. The ambient concentrations of pollutants at ground level is an important indicator of the level of pollution. Such pollutants not only depend on the rate of emissions but also on the meteorological variables such as windspeed and stability conditions. This has been described by an atmospheric model, which considers quantitative descriptions of transport and dispersion of pollutants in the atmosphere. In the present study, we have adopted a set of air quality models to predict the concentrations for point, line and area sources for a given input of windspeed, wind direction, source emission rate and atmospheric stability conditions. The results from the model are of two types—the 95-percentile concentration and the annual mean concentration.

Concentrations in power plants

It is evident that the cause for concern in both the Badarpur and the Indraprastha (IP) power plants, is the high levels of SO_2 and NO_x which have high emission rates *vis-a-vis* other pollutants. Though the source strength of the Badarpur plant is very high, the ground level concentrations are observed to be less than the IP power plant because of higher stack height. It is expected that in 1996/97 (BAU) the ground level concentrations will exceed standards and vary between 190–220 micrograms per cubic metre (pcu.m) for SO_2 and 200–230 micrograms pcu.m for NO_x between distances 1–2.5 km from the stack, at the 95 percentile level. However, in the alternative scenario both the plants have concentrations which meet the standards. (See Table 2 and Table 3).

Table 2. Annual emissions from the power sector (tonnes)

Plant	*TSP*	*SO_2*	*CO*	*HC*	*NO_x*
		1990/91			
IP	510	9936	1307	654	9805
Rajghat					
Badarpur	1227	23 917	3147	1573	23 602
		1996/97			
IP	1181	23 008	3027	1514	22 705
Rajghat					
Badarpur	2755	53 685	7064	3532	52 979

Table 3. Power plants (1990/91): Gaussian-Pume (GPM) model

		95% concentration (ug/m³)	
		SO_2	NO_x
	1990/91		
Distance			
100		0	0
		0	0
500		0	0
		4 24	4 19
900		67 76	66 87
		88 29	87 13
1500		84 36	83 25
1700		90 03	88 84
		81 30	80 23
2100		68 49	67 59
		56 16	55 42
2500		45 71	45 11
		37 26	36 77
2900		30 54	30 14
	1996/97		
Distance (metres)			
100		0	0
		0	0
500		0	0
		9 53	9 4
900		152 09	150 09
		198 18	195 57
1500		189 35	186 86
		202 08	199 42
1900		182 48	180 08
		153 73	151 71
2300		126 07	124 41
		102 60	101 25
2700		83 63	82 53
		68 56	67 66
3100		56 63	55 88
		60 63	59 84
3500		63 38	62 54
		61 93	61 12
3900		58 70	57 93

Concentrations in the transport sector

In the case of the transport sector, annual mean concentrations of TSP, SO_2 and CO exceed standards in the year 1996/97 (BAU). They would be of the order of 514 micrograms pcu.m of TSP, 122 micrograms pcu.m of SO_2, 11 492 micrograms pcu.m of CO, 671 micrograms pcu.m of NO_x, 3275 micrograms pcu.m of HC and 3.25 micrograms pcu.m of Pb. However, it is observed that the concentrations in the alternative scenario are: TSP 513.5 micrograms pcu.m, SO_2 120.83 micrograms pcu.m, CO 11 412 micrograms pcu.m, HC 3242 micrograms pcu.m, NO_x 654 micrograms pcu.m and Pb 3.23 micrograms pcu.m. TSP, SO_2, CO and NO_x exceed the standards.

Concentrations in the domestic sector

In this sector, emissions from the use of kerosene and LPG and subsequent concentration levels are calculated. Given the background concentration for Delhi, it is observed that in 1996/97 (BAU), the annual mean concentrations would be 508.09 micrograms pcu.m for SPM and 3619 pcu.m for CO, both of which exceed standards and 62.8 micrograms pcu.m for NO_x. In the alternative scenario, the concentration of pollutants in micrograms per cubic metre are TSP 507, CO 3545 and NO_x 57. Except for TSP concentrations which are marginally above the standards, the others are well within the limits.

Concentrations in the industrial sector

In the case of the industrial sector, the 95-percentile concentrations of TSP, SO_2 and NO_x exceed standards. The concentrations are predicted to be: TSP 592 micrograms pcu.m, CO 4510 micrograms pcu.m, NO_x 281 micrograms pcu.m, SO_2 230 micrograms pcu.m, and HC 13.14 micrograms pcu.m during 1996/97 (BAU). In the alternative scenario, the concentration levels are 503 micrograms pcu.m of TSP, 72 micrograms pcu.m of SO_2, 3527 micrograms pcu.m of CO, 2.27 micrograms pcu.m of HC and 96 micrograms pcu.m of NO_x and are within the standards.

Conclusion

There is growing evidence that much of our present development is unsustainable and we are reaching and, even transgressing critical ecological thresholds.

It is quite clear that in the short term, the feasible options available for the rational use of energy are not adequate. From this stems the need for a long-term strategy. The alternative scenario developed as part of the short-term strategy represents only an initial step in the long-term commitment that must be taken to maintain ecological integrity. Hence, the choice before us is not whether, but how, to develop. This involves the formulation of a long-term strategy, selecting policy options and taking economic decisions for the rational use of energy.

CASE STUDY III

Contribution of rural household energy use to biomass degradation: A case study from Uttara Kannada (Western Ghats)

Introduction

The forest cover in India decreased from 33% in 1947 to 19% in 1991. Only 60% of the forests have a crown density of 40% and more. Deforestation and degradation take place mainly due to commercial and industrial demand, expansion of agricultural land into forest areas, and needs of fuel, fodder and other produce. The latter two phenomena can be attributed to the rapidly increasing population[1].

The dependence on forest resource is not uniform in all parts of the country and across all sections of the population. 70% of the Indian population lives in the rural areas and the rest in the urban areas. Within this broad division, there are different lifestyles and resource endowments.

The state of natural resources has important ramifications for the country's population. For instance, depleting forests place enormous strain on women and children who would be forced to travel longer distances in search of fuel[2]. This additional burden also has social ramifications as it cuts into the time that should be devoted by women to tending to children and caring about their education, and attending to other household activities. Biomass burning in inefficient, smoky cooking devices causes severe health problems such as chest and lung diseases, eye irritation, and even pregnancy-related complications[3]. Given the dependence of the rural populace on forests for meeting their day-to-day requirements, the depletion of these resources often affects their lifestyles, compelling them to move out to urban areas in search of economic betterment. These interactions among demographic and environmental factors render the population-natural resource linkages rather complex and highly variable over time and space.

Rationale

Energy use in the rural households is the primary cause of deforestation. This had been one of the most common assumptions in the early seventies regarding the process of natural resource degradation in India and most other third world countries. However, as more and more attention was accorded to the issue, the perception began to change. In

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[1] Mukerji, A K (1994), India's forests A status report—Concepts, definitions, trends, controversies, Ministry of Environment and Forests, Government of India

[2] Agarwal, Bina (1986), Cold Hearths and Barren Slopes, Allied Publishers, New Delhi

[3] Smith, Kirk (1993), Household fuels and health, *Urja Bharati*, 3(3) 31–32

India, the national household energy survey conducted by the National Council for Applied Economic Research in 1978/79 showed that 52% of the total energy in the rural domestic sector was contributed by fuelwood alone; and over 75% of it in the form of twigs and branches. This suggested that people may not cut whole trees for fuelwood but only lop the thin wood. On the other hand, several micro-level studies have indicated that commercial and industrial demand for wood, and forest clearance due to demand for agricultural land on account of growing population pressure are the major causes of deforestation.

However, such energy consumption studies also indicate that areas where the resource degradation is already taking place due to the factors enumerated above, rural energy demand may also be contributing to the process. As the resources nearby gradually disappear, people are forced to either spend more time in travelling longer distances to forage for fuel adding to their drudgery; or resort to using inferior fuels like weeds and shrubs leading to health problems; or remove whole trees in the vicinity to meet the fuel demand. And, as the free fuelwood supply diminishes, fuelwood may get monetized creating a market, and once it becomes a commodity, incentive for illicit felling also increases.

Empirical evidence on the contribution of rural energy demand to forest degradation is not readily available. This case study attempts to provide an insight into the role and contribution of rural energy use in biomass resource degradation, if any, through a study of seven selected villages in the coastal tract of the Western Ghats region (Uttara Kannada district) in Karnataka, India.

Objective

To study the contribution of rural household energy use to the process of biomass resource degradation.

Study area

Uttara Kannada is a coastal district situated in the northern part of Karnataka state. The district straddles the range of mountains known as the Western Ghats, that runs parallel to the western coast of the Indian subcontinent. Geologically, this region is a transition between the Deccan trap in the north and the Archean crystalline shield to the south, characterized by broad rolling hills (maximum height 1000m), before merging with the Peninsular plateau in the east at an altitude of 600 m. The district receives an average annual rainfall of 2742 mm. Precipitation ranges from 3000 mm at the crest, decreasing to 1000 mm in the east of the crest line, and is largely confined from June to September.

Topographically, the Western Ghats can be divided into three zones: the eastern tableland, the central belt of hills and valleys, and the coastal belt. The natural humid tropical forest vegetation of the region is governed by the rainfall gradient, changing from predominantly moist deciduous to semi-evergreen to evergreen types, from east to west.

The district is an ecologically fragile zone, possessing a rich biomass resource base and associated biodiversity. About 81% of its total geographical area (10 291 sq km) is classified as forests (Gazetteer of India, Karnataka State, Uttara Kannada District). Even though they are not as significant globally as the other major tracts of humid tropical forests, at least as far as flowering plants are concerned, the Western Ghat forests are still of considerable importance for India and classified as one of the world's biodiversity *hot spots*. They constitute an economic resource, protect watersheds of all the major rivers of the southern peninsula, support livelihoods of substantial peasant and tribal communities, and are a repository of biodiversity surpassed only by the eastern Himalaya. It is a matter of considerable concern therefore that the Western Ghats have suffered substantial outright loss of forest cover, loss of standing biomass in areas retaining forest cover and loss of biodiversity. The district has experienced declining forest cover from 8000–6000 sq.km. over a period of 40 years; a loss of 0.7% per year (Daniels *et al* 1992).

Administratively, the district comprises 11 *taluks*, of which the two *taluks* of Honnavar and Kumta have been selected for the case study. These *taluks* lie in the coastal tract of the district, which is a succession of estuarine plains dotted with paddy fields, belts of arecanut and coconut plantations, and moist deciduous to evergreen forests. Since these *taluks* possess a good network of communication (including a port at Honnavar), they are well developed and also more densely populated. The demand for biomass (fuel, fodder and green manure) in such areas is fairly high. Consequently the resources are considerably stressed despite extensive reserves of forests.

Methodology

The methodology followed for the study can be broadly divided into three components:

- site (village) selection and secondary data collection,
- primary data collection (data on resource productivity and condition, and household socioeconomic characteristics and biomass resource use), and
- data analysis.

The information thus collected was used to compute stress on the biomass resource (only tree resources were considered) by household biomass use, and to suggest options to mitigate the pressure on forests.

Selection of villages

The selected villages represent different scenarios based on socioeconomic (population, distance from urban centres) and environmental (legal status of forests, fuel extraction practices) criteria. The criteria were chosen after examining the secondary data available

(Table 1). Out of the seven villages selected, six (Adukal, Keravali, Heravalli, Dabbod, Manki, Chandavar) are located in Honnavar and one (Antravalli) in Kumta *taluk*, but all fall under the Honnavar forest division.

Table 1. Profile of the selected villages

Village	Population (households)	Cattle	Total area (ha)	Forest area (ha)	Legal status	Fuel extraction
Adukkal	564 (104)	355	642.80	559.67 (87%)[1]	MF[a] + RF[b]	D[c] + C[d] + M[e]
Dabbod	315 (48)	134	195.57	151.73 (78%)	MF	D
Antravalli	1401 (205)	963	1256.76	943.44 (75%)	MF	D + C + M
Keravalli[2]	565 (94)	292	122.91	57.82 (47%)	RF	D
Manki	14828 (2853)	4832	3342.4	2014.09 (60%)	MF + RF	D + C
Chandavar	2881 (452)	901	2134.16	1691.55 (79%)	MF	D + C
Heravalli	302 (47)	342	551.87	493.28 (89%)	MF	D + C
Tumboli[2]			932 73	909.15 (97%)		

[a]minor forests [b]reserved forests [c]domestic [d]commercial [e]Management practices of Forest Department

Notes

1/ The figures in brackets are percentages of forest area

2/ Tumboli, a reserved forest, lies in a vicinity of 5–8 kms from Keravalli. The minor forest of the village Keravalli is virtually a grassland, and obtains its biomass supply from the reserved forest in Tumboli

Secondary data were scrutinized for information on land use (including forest cover), livestock and human population, fuelwood supply from forests depots, etc.. Table 2 summarizes the type and source of secondary information collected for the study.

Table 2. Secondary data sources

Information	*Level*	*Source*
Population, landuse, forest land	Village, *taluk*, district	Census Handbook, District Commissioner's Office, Forest Department
Latest livestock and human population	Village	*Tehsildar's* Office
Fuelwood supply from depots, forest land encroached	Village, division	Forest Range Office, Forest Department

Primary data collection and analysis

Primary data comprised collection of information on resource productivity; household socioeconomic characteristics and biomass consumption. A separate survey was carried out to study the extraction practices, followed and species preferred, by headloaders.

The biomass resource data were obtained through sampling of growing stock (tree and saplings) in the forests adjoining or in the vicinity of sample villages. The villages have been given legal access (concessions) to them for harvesting of biomass for bona fide needs of fuelwood, fodder, construction material, etc. by the Karnataka Forest Department.

Both trees (upper storey) and saplings (undergrowth) were enumerated using the quadrat method. Plots measuring 20 × 20 m and 5 × 5 m for trees and saplings respectively were laid out at random, and all tree species were identified and measured for girth at breast height (GBH) as well as height. Canopy density was calculated, using ocular observations of canopy cover; and stumps were counted. Data thus collected were used to estimate tree and sapling density; species mix; growing stock; sustainable yield and stress factor.

Linked to the vegetation study was the sample household survey, to examine the socioeconomic characteristics of households and biomass resource use for energy needs. The focus was on enduses of cooking and water heating. Questionnaires were administered to households at random and information on family size, occupation, land ownership, livestock, energy consumption, collection and preparation of biomass, etc. were sought. Using the above, patterns of energy consumption were obtained (per capita as well as total). The stress analysis was based on the per capita consumption and biomass supply, and pressure on biomass resources obtained therein. A qualitative analysis of the perception of fuelwood scarcity problem by the households was also carried out.

To support household energy demand and vegetation studies, a survey of the headloaders was undertaken. This exercise was thought necessary so as to ascertain whether harvesting practices and species preference by the headloaders had any impact on the biomass supply. Headloaders in sample villages were interviewed and observed for extraction practices, Tree and sapling species are preferred for energy and non-energy uses, type of load carried and distance travelled.

Status of biomass resource in the villages

The selected villages fall in the coastal *taluks* and are characterized by secondary moist deciduous forests occurring along the river valleys as well as evergreen wood lots around the villages. The hills are lateritic and support poor vegetation. The tree species of the moist deciduous forest are *Terminalia panniculata, T. tomentosa, Xylia xylocarpa, Lagaerstroemia microcarpa, Adina cordifolia, Dillenia pentagyna, Caeya arborea, Albizzia, Odina wodier, Aporosa lindleyana.* The evergreens species associated with such forests are *Garcinia indica, Ochrocarpus longifolius, Carallia integerima, Olea dioica, Hopea wightiana, Mimusops elengi,* etc.

The villages are heavily dependent on non-cultivated land i.e. forest (tree vegetation) for fuelwood, fodder, and structural requirements. Because of the manner in which woody biomass is extracted and used from such lands, the landscape around the villages exhibits a combination of different vegetation types—lands dominated by tree and grass, high/low density trees with no grasses and species composition (deciduous/evergreen).

The structure of tenurial arrangements regulating and mediating the social use of forest resources in Uttara Kannada district is complex, and indeed in some ways unique. The *settlement* and *re-settlement* of forest rights carried out by the British colonialists during 1890–1930 is a watershed in the history of these institutions, and the resultant allocation of forest rights and privileges, embodied in the form of the Kanara Forest Privilege Rules (Anonymous 1944), has remained essentially unchanged since then. All forest lands are nominally owned by the state, but the extent of its control varies significantly by the legal category (Lele 1993). To a large extent, forests of the coastal areas and adjoining human settlements are classified as minor forest with accompanying privileges, while dense forests with low population are classified as forest proper (Buchy, 1990).

In the study area there exist the following categories of forest land—Reserved Forest (RF), Minor Forest (MF), and *Soppinabetta*. Although the rights of all forest land are vested with the Karnataka Forest Department (KFD), the department has maximum control over RF. Local inhabitants are allowed to collect deadwood or graze animals but these privileges can be curtailed at anytime. MF are forest lands assigned for use of residents of a village or group of villages to meet their needs of fuelwood, fodder, leaf manure and other forest products. MFs are to have been assigned in the proportion of 2 acres for every head of livestock in the village at the time of the forest settlement, but proportions were neither strict nor meaningful (Masur 1918), since the villagers have neither exclusive use, nor any formal role in their management (Lele 1993).

Soppinabetta (or *betta* for short) literally means *hill of leaves or leafy matter* (*soppu* = leaves or leafy matter, *betta* = hill). Physically, it referred to the strips or patches of treeland on the hill slopes adjoining the areca orchards that were traditionally lopped by the areca cultivators for mulch, animal bedding, manure, and fuelwood. Legally, it refers to the specific piece of forest land *attached* or assigned to a specific orchard plot, conferring exclusive privileges on the owner of that orchard plot. These privileges include lopping of trees for mulch, manure and fuelwood, livestock grazing and fodder collection, and even obtaining timber from these lands for personal use upon obtaining the sanction of and making a (till recently nominal) payment (Lele 1993).

All villages have been assigned MF. In addition only two villages—Adukal and Manki possess RF. But village Keravalli, whose MF is virtually a grassland (according to village forest records the MF assigned to the village has been historically so), obtains its biomass supply from an RF in the vicinity (5–8 km), called Tumboli. However, all villagers extract firewood, leafy matter fodder and construction material from the nearest forests, irrespective of their legal status. Harvesting is not limited to the respective village but also extends to meeting the biomass needs of other villages in the vicinity. The exception of Keravalli forest lands in respective villages accounts for more than 60% of the total land area.

Consumption pattern in villages

For the purpose of this study, only woody biomass for the enduse of cooking and water heating is focused on. Households use biomass from uncultivated land (mainly forests) for their domestic needs or as inputs for livestock and agriculture production.

For the end use of cooking, households burn twigs, logs, billets and for water heating, fuelwood is supplemented by coconut and arecanut husk, and dry leaves. In fact, water heating, an activity which is carried on throughout the year is a major consumer of biomass. It is quite common to see large water-filled copper/iron urns placed on smoldering fires at any time of the day in homes. From the results of the household survey, the average per capita fuelwood consumption for cooking and water heating is 3.12 kg per day, but variation exists across villages.

The fuelwood for the above needs is harvested in the form of dead twigs, branches, logs, and shrubs. However, affluent households mostly meet their firewood requirements from private lands or else have access to biogas or LPG. These households also use agricultural residues (coconut and arecanut husk and leaves) for water heating. Small and marginal farmers are wholly dependent on forests for fuelwood. Although there is the provision of fuelwood depots run by the forest department to supply firewood to locals, the supplies are rationed—15 kg/person/month at Rs 24.80 per quintal. This quota is, however, grossly inadequate to meet the average monthly per capita need of 93.60 kg (more than six times the quota). Moreover fuelwood is collected at zero cost, so the villagers are reluctant to purchase wood from depots even if it is available. Also, in certain cases, the depots are far away from the villages and the inhabitants have no choice but to harvest their needs from a nearby forest area.

While consumption of fuelwood is also affected by the technology used, almost all households except for those with biogas, use traditional (two-pot) stoves for cooking and one-pot stove for water heating. The introduction of improved cook-stoves is yet to be initiated in these villages.

For non-energy uses such as manure, animal breeding and milking, households rely heavily on leafy matter—green leaves (*soppu*) for manuring arecanut orchards and dry leaves (*darku*) for their paddy fields. Leafy matter is harvested by lopping, and also gathered as litter. It was observed that irrespective of land-holding size, most households possessed cattle. These were either grazed or stallfed. During the wet season when green grass is abundantly available, the cattle are allowed to graze freely, even in forest lands. In the dry season, a combination of stored dry grass and /or agriculture residues serves as fodder.

Besides demand for fuelwood, households require timber for construction of houses, and small timber, bamboo poles, thorny shrub, creepers and grasses (cane and bamboo) are used for fencing and other agricultural operations. Saplings are harvested for fencing purposes. However, demand for non-energy purposes as above is not on as regular a basis as fuelwood, though a sizeable demand does exist.

Headloading

An interview-based survey and field observation of the headloaders provided insight into the pattern of harvesting, transportation and disposal of biomass. Headloading is mainly practised by households which are wholly dependent on public lands for their domestic needs; and by those who work as labourers for the plantation farmers. Besides headloading for bona fide needs, there also exists the practice of headloading/cart loading for commercial purposes i.e. for sale to households, road-side eating establishments, and industrial units.

The composition of the load carried varies with the needs of consumers and different techniques are adopted to harvest the load. For fuelwood, dead twigs and branches are picked, lops and tops and billets from dead trees (remnants of trees felled for timber) are collected. Some of the species preferred for this are *sagadi, hedmangala, salle* (*Aporosa lindleyana*), *holigere* (*Holigarna arnottiana*) *thare* (*Terminalia bellirica*) *mullu, acharkalu* (*Olea dioica*) and suragi. Leafy matter is lopped for fodder and green manure; for which shrub species such as *gurge, narthe, hedalu,* and *eupotorium* (which is considered a weed) are preferred. The material for fencing of encroached lands is collected annually but involves cutting of poles of 1–1.5 metre height and generally up to 50 cm GBH of selected species—*thare, gurge, hedalu.* Lopping as a harvesting practice is most preferred, followed by chopping dead wood, picking fallen wood, and girdling to kill the trees. The headloaders use a combination of these techniques to extract biomass. Till 1983, there was no restriction on the type of biomass (including green wood) that could be collected by the headloaders but thereafter, the forest department allowed only dead and fallen biomass and leafy matter to be extracted.

Headloads are also transported by cycles or even by carts. A large number of headloaders comprised women and children (girls), and most of them, irrespective of sex, were in the age group of 20–40 years. Women normally carry loads of dead twigs and branches, and billets weighing between 15 and 40 kg. Men carry logs and billets of weights ranging from 30–45 kg. Cycles and/or carts are operational where cart tracks exist in forests and are generally used to transport loads meant for sale. Loads weighing

40–60 kg and 200–300 kg, respectively, are carried by these modes while the distance travelled by headloaders ranges from 3–10 km (average 5 km).

Biomass is usually collected in winter and summer months and stored for the rainy season. Households make at least one trip a day for collection. The frequency of visits to the forests varies from 3–7 per week.

Stress on biomass resources

A stress analysis was carried out to determine whether household energy use is a contributing factor to the degradation of biomass resources and to establish whether the correlation perceived between degradation and energy use is supported by the vegetation studies undertaken. The analysis reflects the balance between supply (in terms of sustainable yield), and demand (based on household consumption of fuelwood for cooking and water heating) for biomass resources.

Also, a qualitative analysis of people's perception of the fuelwood crisis was carried out to ascertain the ground realities. Besides this qualitative information, variables pertaining to forest resources were examined to highlight the stress.

It is clear from Table 3 that resources are under stress from local use. The resource, in villages Dabbod and Keravalli, which are chiefly stressed for bona fide domestic needs, has a stress factor of 4.12 and 0.68, respectively. In contrast, stress was 1.9 and 2.16 in Adukal and Antravalli, where biomass is harvested for commercial (FD) as well as domestic purposes. However, in villages where illicit felling was reported; stress ranged from 0.8 to 7.8. Keravalli and Heravalli (stress factor is less than 1 indicating little or no stress) villages did not exhibit stress.

Table 3. Stress on resources in selected villages

Village	*Per capita consumption of fuelwood (kg/day)*	*Total use fuelwood (tonne) (annual)*	*Sustainable yield (tonne) (annual)*	*Stress factor*
Adukal	4.24	872.80	404.90	2 16
Dabbod	3.30	378.60	76.70	4.12
Antravalli	3.00	152.80	803.30	1.90
Keravalli	3.28	675.90	998.91	0.68
Manki	1.68	910.75	1379.49	6.60
Chandavar	3.69	3884.57	497.67	7.80
Heravalli	2.66	292.76	365.54	0.80

Canopy density

The canopy density ranged from .20 in Dabbod to 1.38 in Antravalli. All villages, except Keravalli and Antravalli had canopy densities of less than 1. The number of stumps observed was highest in Keravalli (76) and least in Heravalli(9). Similarly, basal area ranged from 2 in Dabbod to 9.6 in Antravalli (Table 4).

Table 4. Ocular observations on forests in selected villages

Village	Canopy density	Number of stumps
Adukal	0.66	12.00
Antravalli	1.38	9.80
Chandavar	0.625	22.30
Dabbod	0.202	8.80
Heravalli	0.939	9.00
Keravalli	1.086	76.25
Manki	0.263	20.81

Girth class-wise number of species and trees

The distribution of tree species in different girth classes was observed. It was found that in all the villages tree species in girth class of 50–80 cm, were much below the number of tree species in the subsequent girth classes (Table 5). This reduction reflects loss of certain species because of human pressure, probably for fuelwood or fencing posts as this girth class cannot yield timber.

The number of trees in various girth classes also exhibits the same trend as the number of species. In the girth class of 50–80 cm too, there is a significant reduction (Table 6). This indicates a gap in the number of trees to be recruited to higher girth classes, consequently reducing the growing stock at maturity

Saplings

The existence of saplings is an evidence of regeneration of the undergrowth. The average number of saplings is as low as 28 in Dabbod and as high as 113 in Chandavar. The number of species at the sapling stage varied between 20 and 29, except for village Dabbod, which had only 10 species at this stage.

Height class

As in the observations of tree species and numbers in various girth classes, a similar trend was seen in the height class. In the height class of 5–10 m, the pole stage, a substantial decrease in the number and species of trees was recorded (Table 7 & 8). This clearly shows that biomass resources in the concerned height class are stressed because of heavy extraction.

The variables discussed above, reflect stress in terms of species lost as demonstrated by the change in number of species in a particular girth/height class; and reduction in growing stock indicated by the number of trees (in different girth/height classes), caused by excess harvest for domestic and commercial purposes.

The evidence of stress (stress more than 1) in the selected villages suggests that sustainable supply from local resources is inadequate to meet the demand. In the villages

Table 5. Distribution of species in different girth classes

Villages	Total*	Girth class (cm) 20–50	50–80	80–110	110–140	140–170	170–200	200–230	230–260	260–290	>290
Adukal	24	10	4	11	8	3	5	2	—	—	—
Antravalli	35	14	9	11	4	1	2	3	—	2	1
Chandavar	25	12	8	10	8	4	2	1	1	—	—
Dabbod	15	11	3	4	1	1	2	3	1	1	—
Heravalli	32	14	12	15	5	3	1	2	—	1	—
Keravalli	39	29	10	5	5	1	2	4	—	1	2
Manki	20	9	7	6	5	3	1	1	2	2	—
Average	27.14	14.14	7.57	8.86	5.14	2.29	2.14	2.29	1.33	1.40	1.50

*Total means total number of species observed in the area

Note. It is not essential that the sum of species in various girth classes equal *Total*

Table 6. Number of trees distributed in various girth classes

Villages	Girth class (cm) 20–50	50–80	80–110	110–140	140–170	170–200	200–230	230–260	260–290	>290	Total
Adukal	17.3	6	11.7	10.5	4	6	2	—	—	—	57.41
Antravalli	21.3	12.3	14.3	6	1	2	3	—	2	1	63.00
Chandavar	19.5	11	11.3	10.98	4	2	1	0.5	—	—	58.62
Dabbod	12	3	6	1.5	1	2	3	1	1	—	30.50
Heravalli	16.3	19	21	6	4	1	2	—	1	—	70.33
Keravalli	66.5	13	7	5	1	4	4	—	1	2	103.50
Manki	10.7	8	8.5	5	4	1	1	2	2	—	42.17
Average	23.38	10.33	11.40	6.25	2.71	2.57	2.21	1.17	1.40	1.50	

Table 7. Number of species at sapling stage in different villages

Village	*Species*	*Number of saplings*
Chandavar	26	113
Antravalli	20	75
Keravalli	22	55
Dabbod	10	28
Adukal	20	64
Heravalli	29	104
Manki	23	87

Table 8. Average numbers of trees in different height classes

Village	*2.5–5*	*5–10*	*10–20*	*20–30*	*>30*
Adukal	6	2	4	3	0
Antravalli	5	4	4	2	2
Chandavar	8	6	3	1	0
Dabbod	3	0	2	0	1
Heravalli	6	2	5	2	3
Keravalli	9	3	2	2	1
Manki	6	2	1	1	1

where stress is negligible, the population to be serviced is low when related to large reserves of forest lands. Hence, stress in any village implies that either the resource is degraded (productivity is low), or the harvest is more than the sustainable yield. In such situations, villagers are compelled to go beyond their respective villages to other public or government lands or to walk longer distances in search of fuelwood. It is also possible that people may shift to timber species or shrubs for fuelwood purposes. If such a scenario exists, the biomass resources are threatened or are in the process of depletion and the pressure on the resources is fairly obvious.

The stress calculated is also supported by the qualitative analysis of the perception of *fuelwood* crisis by the villagers. A majority of them stated that the extent of forest cover had declined over the years, forcing them to walk longer distances than before. The decline was attributed to population growth and timber smuggling. However, they did not experience fuelwood scarcity. So long as it is available freely (at present), the question of scarcity does not pose a severe problem, even if it means physical discomfort. Moreover, awareness about the environmental impacts of deforestation is virtually non-existent. Ironically, fuelwood crisis ranks low on the priority list of the inhabitants; infrastructural development such as roads, medical care, and education take precedence.

Conclusion

The forest lands in the study area are used in a variety of ways by the rural households of the Western Ghats region. This variation in use, reflects the complexity and diversity of individual and collective biomass extraction and use practices. The extent to which the household sector contributes to degradation (in terms of stress on biomass resources), is apparent from the foregoing results of stress analysis and other related patterns of use, characteristics of household and rights concerning accessibility to forests.

It is evident from the field observations and questionnaire surveys, that all households irrespective of land holding size, use biomass from public lands. While majority of the headloaders and cart loaders claimed that harvesting was carried out for bona fide needs, commercial headloading/cartloading is fairly rampant. The forest department also contends that cart loading for commercial purposes (for supply to households engaged in tertiary/service occupations, roadside eating establishments, and even tile factories which have quotas from the forest department), is a major contributor to degradation of MF lands. Moreover, illegal extraction of timber from such lands is yet another factor resulting in the cutting of trees. As there are operational problems in monitoring or checking the illicit extraction and transport of timber, no information is available as to how much the loss is over time.

Encroachment of forest land for agricultural purposes is yet another major problem faced by the forest department. According to the FD (personal communication), about 10% of the forest land has been encroached to date. A number of cases are pending against defaulters.

A distinct impression of the region is the abundance of forest-based biomass and its lavish use by the villagers. The high per capita domestic consumption of fuelwood is an evidence. Many analysts have also commented upon this lavish level of consumption in other parts of the Ghat region (Lele 1993). Further, the predominant use of traditional cooking devices coupled with the low penetration of renewable energy technologies has exacerbated the unsustainable fuelwood use. In view of the prevailing pattern of biomass extraction and use, accelerated degradation is anticipated in future due to headloading/cart loading and domestic demand.

In view of the fuelwood problem, it becomes imperative to identify the opportunities for change and look for suitable policy options to alleviate the situation. Some steps that could provide solutions are:

- to elicit support from grassroots level NGOs to create awareness about stress on resources, using techniques of mass communication, especially the traditional folk art medium,
- introduction of renewable energy technologies, such as improved chulhas, biogas and solar water heaters which are also feasible alternatives for the area,

- improvement of management of the existing resource base, through private or community-based initiatives by utilizing local expertise and resources. Because of the area's good biomass potential, fuelwood supply enhancement interventions, depending on groups which have access to land (farm land) are to be designed. Agroforestry can be introduced in private lands, and for the landless/land-poor groups, communal management of common lands by way of joint forestry management, and
- energy interventions have to be in conjunction with development priorities if these are to be successfully implemented.

It is clear that continuation of the process of degradation would lead to environmental discontinuity or *jump* effect, in which the carrying capacity of the forests will reach a totally unsustainable limit for future generations. The well-being of the area depends on the sustained productivity and management of the environment, and on equitable access to natural resources for all sections of the people. This requires both conservation and sustainable development.

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CASE STUDY IV

Talcher coalfield

Production and despatches

There are four underground and six opencast mines presently in operation in the Talcher coalfield. The total coal production in 1992/93 was 15.3 Mt, of which the opencast mines contributed 14.8 Mt (97%). The details of coal reserves, mine capacity, production and land requirement etc. for each mine are given in Table 1. Nearly 15 million cubic metres of overburden material was removed from the opencast mines in 1992/93

The coalfield is catering to the requirements of a fertilizer industry, the Talcher thermal power station, and an aluminium plant. The consumption of coal in 1992/93 was as follows in Table 1.

Table 1. Consumer-wise despatches in 1992/93 (Mt)

Consumer	*Road*	*Rail*	*Belt*	*MGR*	*Total*
FCI (pit-head) NALCO (pit-head)	0.16	—	0.35	3.23	3.74
TTPS (pit-head)	0.16	—	1.15	—	1.31
Other industries in the region	1.30	0.78	—	—	2.10
TPS located away from coalfield (southern region)	—	6.86	—	—	6.86
Total	1.60	8.32	1.50	3.20	14.70

Future expansion

The coal demand from this coalfield is projected to increase from 15 Mt in 1992/93 to 25.4 Mt in 1996/97 and 31.8 Mt in 2001/02, largely from thermal power stations located in the southern region (Table 2). The recent reduction in import duty on non-coking coal coupled with entry of private sector power generators in the southern and western regions, has made it difficult to assess the demand beyond 1996/97 with any degree of accuracy.

Table 2. Coal demand projections from Talcher (Mt)

	1996/97	*2001/02*	*Remarks*
Industries	1.2	1.3	Within the region
Captive power stations	6.6	6.8	Pit-head
Utilities (Talcher)	1.2	3.0	Pit-head
Utilities (Southern region)	16.4	20.7	Outside the region
Total	25.4	31.8	

A production plan has been prepared to meet the demand Table 3 and a coal evacuation plan tentatively drawn up in Table 4.

Table 3. Coal production plan (Mt)

	Actual	*1996/97*	*2001/02*
Item	*1992/93*	*(Projections)*	
Existing mines	5.8	5.2	5.2
Approved ongoing projects	9.5	21.3	24.8
Projects formulated, yet to be approved	Nil	0.7	1.8
Total	15.3	27.2	31.8

Table 4. Coal evacuation plan (Mt)

Mode of transport	*Actual 1991/92*	*1996/97*	*2001/02 (Tentative)*
All rail	6.8	5.3	10.0
Rail-cum-sea		10.1	11 0
Other measures (Belt, road, MGR)	6.3	10.3	11.0
Total	13.1	25 7	32.0

A major part of the movement would be by rail to distant consumers. Paradip port is the nearest port from Talcher and is well suited for handling the traffic bound for the distant southern region thermal power stations. This port is under expansion for handling additional coal traffic. The other potential port is Gopalpur which requires major reconstruction to handle coal by mechanized means. The share of movement of coal by ring rail to thermal power stations at pit-heads would also increase substantially.

Impact of mining and other activities on the environment in Talcher

With the beginning of opencast mining at South Balanda, Jagannath and other new projects, large-scale degradation of land due to quarrying as well as dumping of overburden has been seen. The proposed large-scale expansion of mining, which will be mostly through opencast operations, will have a substantial impact on the land, forests, atmosphere and water resources in terms of quantity and quality. Besides, the acquisition of land on a large scale for mining will inevitably lead to the displacement of people from the villages in the mining area, and they would have to be rehabilitated outside the mining area.

Environmental degradation would also take place in the area due to several other industrial activities like thermal power plants, fertilizers, aluminium and other industries. All these activities are already contributing to air and water pollution leading to adverse impacts on the vegetation as well as on the people living in the area. The existing industrial activities include Talcher power station (470 MW), operated by the Orissa State Electricity Board, a captive thermal power station of 600 MW being constructed by the aluminium plant, a fertilizer plant and, in addition, a super thermal power plant which is under construction in the area.

Impact of mining on land

The total land required for mining up to 2001/02 is as follows in Table 5.

Table 5. Land requirement for mining up to 2001 (ha)

	For quarrying	For external OB dumps, mining infrastructures, etc	Total	Forest component
Up to 1989/90	700	300	1000	50
1990–95	500	380	880	100
1996–2001	400	300	700	150
Total	1600	980	2580	300

This large scale acquisition of forest land for mining would have to be linked with a forest restoration programme through appropriate land reclamation, top soil buildup, and planting. A land reclamation programme has been drawn up which is as follows (Table 6).

Table 6. Land reclamation plan (ha)

Period	For existing mines	New mines	Total
Up to 89/90	90	–	90
90/91 up to 2000	210	325	535
Total	300	325	625

Compensatory afforestation

It is also suggested that degraded forest areas in the coal bearing area which are unlikely to be mined in the next 30 years may be brought under the afforestation programme. A plan has been prepared for afforestation up to 2001. The details are as follows in Table 7.

Table 7. Afforestation plan (ha)

Compensatory afforestation	1400	(Twice the forest land acquired for mining)
On reclaimed land	300	
Afforestation on degraded forest land within mining area which is not to be mined in the near future	1100	
Forest around village	240	

Rehabilitation of affected population

About 32 villages are likely to be affected by mining operations up to 2001 and the number of families likely to displaced is about 3000. The rehabilitation package approved by the state and Central Governments would be followed.

APPENDIX 1

Mathematical formulation of TEESE model

Equations

I. Supply–demand balance

$$\sum e_{iba} Y_{iba} \geq D_{ja} \tag{1}$$

II. Electricity Sector

A. Electricity demand

$$TEL = \sum_{b,a} Y_{kba} \tag{2}$$

B. Generation of load duration curve

$$AVGLD = \frac{TEL \times (1+\alpha)}{8760} \tag{3}$$

$$PL = \frac{AVGLD}{\beta} \tag{4}$$

$$LD_m = f_m \times PL \tag{5}$$

C. Demand–production balance for electrical energy for various modes of load.

for base load

for intermediate load

$$\sum_{l} [1-\gamma_l] \times GEN\ (l,\ base) + \varepsilon_{l=ps} \times \sum_{m\,=\,peak\ and\ low\ peak} GEN\ (l{=}ps,\ m) \geq 8760 \times LD_{base} \tag{6}$$

$$\sum_{l} [1-\gamma_l] \times GEN\ (l,\ intermediate) \geq (LD_{intermediate} - LD_{base}) \times (Duration\ of\ intermediate\ load) \tag{7}$$

Same equation for peak and low peak load

D. Peak load guarantee condition

$$\sum_{l,m} \frac{\delta_l \times GEN\ (l,m)}{\theta_l \times 8760} \geq PL \tag{8}$$

E. Fuel requirement in the power sector

$$F_f = \sum_{l,m} \sigma_{fl} \times GEN\ (l,m) \tag{9}$$

III. Balance equation for intermediate energy and final energy

$$\sum_{s} X_{ps} + I_i = \sum_{a,\ b} (1 + \mu_p)\ Y_{pba} + E_p \tag{10}$$

IV. Production-supply balance equation

$$I_s + S_s = \sum_{i} (1 + \rho_{is})\ X_{is} + F_f + E_s \tag{11}$$

IV. Environment

$$ENVq = \sum_{b,\ a,\ i} \lambda_{qabi} \times Y_{iba} \tag{12}$$

V. Objective functions

$$Z = \sum_{i,s} c_{is}^{X} X_{is} + \sum_{i,b,a} c_{iba}^{Y} Y_{iba} + \sum_{s} c_{s}^{S} S_{s} + \sum_{i} c_{i}^{I} I_{i} - \sum_{i} c_{i}^{E} E_{i}$$
$$+ \sum_{l} c_{GEN(l)} GEN(l) + CRF(r,n) \left[\sum_{i,s} \pi_{is}^{X} X_{is} + \sum_{s} \pi_{s}^{S} S_{s} + \sum_{i,b,a} \pi_{iba}^{Y} Y_{iba} + \sum_{l} \pi^{GEN(l)} GEN(l) \right] \quad \textbf{(13)}$$

Indices

i = primary and secondary source of energy
b = appliance
a = enduse
j = economic sector
k = electricity
m = peak, low peak, intermediate, base in the load duration curve.
l = power generation technology (coal, hydel, nuclear etc.)
ps = pump storage
f = natural gas, coal, fuel oil
p = intermediate energy form
s = primary energy form
q = type of pollutant (SO_X, NO_X, etc.)

Parameters

e_{iba} = efficiency of i*th* fuel used in b*th* appliances, for a*th* enduse
α = transmission and distribution losses (exogenous)
β = system load factor (exogenous)
f_m = non-peak load as fraction of peak load (exogenous) (m is not equal to peak)
$\varepsilon_{l=ps}$ = efficiency of pump storage plant
γ_l = auxiliary consumption of the technology
δ_l = peak availability of technology *l* (exogenous)
θ_l = plant load factor of technology (exogenous)
σ_{fl} = specific fuel consumption (kcal/kWh) by l*th* type of technology (exogenous)
μ_p = losses related to deliver p*th* fuel at consumer end (transportation, transmission and distribution etc.)

ρ_{is} = conversion losses (refining, washing etc.)

λ_{qabi} = emission of q*th* type of pollutants per unit of i*th* type of energy product used in b*th* appliances for a*th* enduse.

c^{X}_{is} = the non-fuel operating and maintenance cost of converting s*th* energy form into i*th* product.

c^{Y}_{iba} = the non-fuel operating and maintenance cost of using i*th* energy form in b*th* appliances to meet a*th* enduse demand.

c^{S}_{s} = non-fuel operating and maintenance cost of productiion of s*th* energy source.

c^{I}_{i} = CIF cost of importing of i*th* energy form.

c^{E}_{i} = FOB cost of exporting of i*th* energy form.

$c_{GEN(l)}$ = non-fuel operating and maintenance cost of generation of power from l*th* type of technology.

CRF (r,n) = Capital Recovery Factor (for interest rate *r* and life *n*).

π^{J}_{i} = capital cost for the variable J_i

Variables

D_{ja} = final energy demand for a*th* enduse in j*th* economic sector[1]

Y_{iba} = i*th* form of energy utilized in b*th* appliances to meet a*th* enduse demand

TEL = total electricity demand at consumer end

AVGLD = average load in the power system

PL = peak load

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[1] D_{ja} is exogenous for all the enduses in all the sectors excepting process heating in the industrial sector and electricity requirement in non-energy intensive industries Input-Output model and energy/electricity intensity for industrial subsectors are used to determine energy/electricity requirement for these two enduses

LD_m = m*th* mode of load

$GEN\ (l,m)$ = generation from l*th* technology during m*th* mode of load

l

F_l = fuel required for secondary power generation

X_{ps} = form of p*th* intermediate energy produced domestically from s*th* primary sources

I_p = import of p*th* form of energy product

E_p = export of p*th* form of energy product

S_s = domestic supply of s*th* primary energy form
ENV_q = amount of q*th* type of pollutants obtained from energy sector
Z = energy system cost.

APPENDIX 2

Economic and demographic data

Economic and demographic data

The Planning Commission, which undertakes the planning exercises for the various Five-Year Plans, has postulated that the growth of the Gross Domestic Product (GDP) during the Eighth Five Year Plan (1992–1997), would be at an average compound annual rate of about 5.6%. In the next two Plans, the economy is projected to grow at a rate of 6.05% (1997–2001) and 6.51% (2001–2006). For purposes of this study, an average GDP growth rate of 6 per cent is assumed throughout the period of analysis. This is consistent with the approach followed in the MEDEE-S[1] report.

Having assumed an average growth rate of 6 per cent for the economy, the share of the various sectors in total GDP was projected which would be consistent with the above growth rate. This projection was made on the basis of a linear relationship between a historical time trend (about 10 years) between the GDP and the various broad economic sectors. Having then determined the share of manufacturing, agriculture, mining, electricity, gas, transport, trade and services etc., the growth of individual subsectors of each was projected, based on a time trend of the relationship between the individual subsectors and the corresponding economic sector.

Some of the subsectors are still too broad to be compatible with the sectors used in this study. In such cases, adjustments have been made for the individual growth rates on the opinion of experts in the relevant field.

All investment and maintenance costs, fuel prices and import and export costs are in 1991/92 prices. A common discount rate of 10% has been assumed. The population growth rate for purposes of demand projections is based on the projections of the Standing Committee on Population Projections. Based on the Input/Output model of 1989 of the Planning Commission which has been updated to 1991/92 prices, the relevant coefficients for import and export have been used. Relevant constraints for the balance of payments have been chosen.

Demand data

On the demand side, based on the projections by the respective demand modules, gross energy requirements for different enduses for household and agriculture have been used. For transport, the gross requirement of passenger kilometres and freight kilometres has been considered. Based on a time trend analysis, commercial energy requirement is been considered. Based on a time trend analysis, commercial energy requirement is projected. As far as industrial demand is concerned, for the energy intensive industries considered in this study, the gross energy requirements for heating and electric power/drive have been taken as projected by the submodule. For other industries, the input/output coefficient was used for various years to obtain the data on gross energy requirements for different enduses.

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[1] Sectoral energy Demand in India, August 1991, New Delhi Planning Commission, Government of India.

Technology data

The model contains a large number of technologies for the demand-and-supply sectors. Since the aim of the study is to develop environment friendly strategies, the new technologies considered in all the sectors are in this direction. In the following sections, technology data refers to what is expected for the different periods of the study. In the base case, we have assumed marginal efficiency improvements over the years based on discussions with the coordinators of the various submodules. It must be noted that the technology data presented, with respect to the costs and efficiencies of operation, only refer to some national average applications of these technologies. In reality, the use, the size and the cost of a technology is more variable. Most of the options for efficiency improvements have only been on the technical side. Options for improvements through better management practices and behavioral changes have been largely ignored, except in the case of electricity distribution losses where the reduction of theft of power through more administrative control is considered.

The technology list, of course, consists of technologies which are existing, even though environmentally, many of them may not be the most efficient or very sound, environmentally. However, wherever possible, the option of gradual phasing out of these technologies is considered. All costs of these technologies are in 1991/92 prices and expressed in rupees.

Technology data households

The various enduses considered in the domestic sector are: cooking, lighting, water-heating, space-heating and space-cooling. The gross energy demand for urban households is determined by multiplying the per capita energy consumption norm for the enduse with the projected population level in each income class, and then aggregated over all the income classes. For the rural domestic sector, the figure for gross energy requirement for cooking and lighting is directly taken from the demand projections made by this submodule. The technologies considered here are associated with only one efficiency for the various years (i.e., the efficiency of their operation is not assumed to vary over the years in the base case). Table 7.2.1 illustrates the efficiencies of the various technologies assumed for use in the domestic sector.

Table 7.2.1. Efficiency of selected technologies for domestic enduses

(Unit: kcal/kcal except lighting which is expressed in lumenhour/kcal)

	Cooking	Water heating	Space heating	Space cooling	Lighting
Crop residue	0.10	0.10	0.20	—	—
Traditional firewood stove	0.10	0.10	0.20	—	—
Improved firewood stove	0.20	0.20	—	—	—
Dung-cakes	0.10	0.20	0.20	—	—
Gas stove	0.60	0.60	—	—	—
Kerosene based wick stove	0.40	0.40	—	—	—
Biogas stove	0.50	0.50	—	—	—
Solar cooker	0.40	0.40	—	—	—
Microwave oven	0.90	—	—	—	—
Electric geyser	—	0.80	—	—	—
Electric room heater	—	—	0.85	—	—
Electric fan	—	—	—	0.80	—
Air-conditioner	—	—	—	0.85	—
Incandescent bulb 40 W	—	—	—	—	0.012
Tubelight 40 W	—	—	—	—	0.051
Compact fluorescent lamps 16 W	—	—	—	—	0.063

While setting the constraints, limits have been placed on the use of biogas plants and compact fluorescent tubes, and availability bounds on firewood and other crop residues. The bounds used are as follows in Table 7.2.2.

Table 7.2.2. Availability bounds on firewood and other crop residues

(Unit: million gigacalories)

	1996/97	1997–2001	2002–07	2007–11
LPG	29.89	35.96	43.29	52.12
Kerosene	44.96	52.00	60.08	69.29
Softcoke	27.50	31.80	36.70	42.25
Dung-cake	16.29	18.00	19.94	21.96
Crop residue	2.31	2.31	2.31	2.31
Solar energy	3.80	4.30	2.70	7.80

Technology data agriculture

Energy demand for the agricultural sector consists of the demand for a few energy intensive crops considered in Chapter 5. The gross energy requirements for two uses—irrigation and land preparation—are fed exogenously into the model. The fuels used for these two purposes are electricity and diesel. The technology matrix consists of pumpsets of two fuel types, tractors and the use of the bullock which is still a means of ploughing and preparing the land for cultivation. The characteristics are listed out in Table 7.2.3. No bounds have been assumed for the use of the two commercial fuels or for the use of bullock.

Table 7.2.3. Cost and efficiency for new agriculture technologies

	1996/97	*1997–2001*	*2002–07*	*2007–11*
Efficiency				
New electric pumpsets	0.300	0.320	0.340	0.340
New diesel pumpsets	0.200	0.220	0.240	0.240
Bullock	1.000	1.000	1.000	1.000
Tractors	0.250	0.260	0.280	0.300
Existing elect. pumpsets	0.300	0.300	0.300	0 300
Existing diesel pumpsets	0.200	0.200	0.200	0.200
Cost (Rs/Gcal)				
New electric pumpsets	0.135	0.135	0 135	0.135
New diesel pumpsets	0.183	0 183	0.183	0.183
Bullock	26.780	26 780	26.780	26.780
New tractors	0.903	0.903	0.903	0.903
Old tractors	0.117	0.117	0.117	0.117

Technology data transport

The demand for total passenger demand and freight demand is estimated outside the model by the submodule. Given certain technologies to meet these demands, the fuel mix and the modal mix for transport demand is determined by the model. The conventional modes like rail (diesel, coal and electricity based) and road (truck, bus, 2-wheeler, 3-wheeler,car) have been considered, but in the energy conservation scenario, the use of compressed natural gas (CNG)—based road transport is also considered. Again, the efficiency and costs are only averages for a representative car or bus. The efficiencies have been worked out on the basis of the average capacity of a particular mode to carry passenger or cargo. The bounds on the use of electricity in transport have been taken exclusively for passenger demand. But no new avenues for use of electricity for passenger transport have been assumed beyond the already existing ones. The technology listing is given in (Table 7.2.4 and Table 7.2.5).

Technology data industry

Industry demands for heating purposes for the base case are based on the input/output coefficient for all the industrial sectors. For electrical energy requirement, data for the nine energy intensive industries have been taken from the submodule, and data for the other industrial sectors has been based on the input/output coefficient. Demand for hot metal production for the steel sector and feedstock requirement for the petrochemical and fertilizer sectors have also been based on the input/output coefficient.

Table 7.2.4. Efficiencies and cost of transport modes

	Efficiency (kcal/passenger km or kcal/tonne km)	*Cost (Rs/kcal)*
Passenger bus	84	0.4747
Passenger 3-wheeler	221	1.638
Passenger 2-wheeler	115	3.843
Passenger motor-bike	118	7.666
Passenger car	223	6 800
Passenger taxi	552	3.848
Passenger diesel locomotive	38	0.415
Passenger electric locomotive	14	0.219
Passenger coal locomotive	364	0.726
Freight LCV	1440	0.842
Freight truck	397	0.580
Freight 3-wheeler	1008	0.655
Freight diesel rail	64	0 641
Freight electric rail	21	1.846
Freight coal rail	921	2 039

Table 7.2.5. Percentage share bound of various modes for the different years

	1996/97	*1997–2001*	*2002–07*	*2007–11*
Passenger road	0.77	0.80	0 82	0.84
Passenger rail	0.22	0.19	0 17	0 15
Freight road	0.44	0.48	0.50	0.51
Freight rail	0.58	0.56	0.54	0.52
Gasoline road	0.26	0.44	0.55	0 66
Passenger diesel rail	0.56	0.52	0.46	0 40
Freight diesel road	0.99	0.99	0.99	0 99
Freight diesel rail	0.50	0.42	0 35	0.27

It is assumed that in the cement sector, 10% of manufacture will be through the dry process and 90% will be through the wet process. 25% of the electricity requirements for industry will be through captive generation. The assumptions for feedstock requirement for hot metal production are that, 40% would be met from domestic coal, 15% from natural gas, 10% from noncoking coal, and 20% from imported coking coal. In the fertilizer industry, 87% would be of nitrogenous fertilizer, out of which 67% would be gas based, other 15% would be fuel oil based, and 17% naphtha based. The portion of steel produced through blast furnace will be about 60% and that through electric-arc furnace will be 40%.

The efficiency and costs of using different fuels for process heating is listed out in Table 7.2.6.

Table 7.2.6. Costs and efficiencies of different fuels for process heating

(Unit: Rs/1000 useful kcal)

	1996/97	*1997–2001*	*2002–07*	*2007–11*
Efficiency				
Non-coking coal	0.5500	0.580	0.600	0.600
Coking coal	0.6000	0.620	0.640	0.640
Natural gas	0.7000	0.720	0.740	0.760
Fuel oil	0.7000	0.720	0.740	0.760
Cost				
Non-coking coal	0.0180	0.015	0.013	0.013
Coking coal	0.0183	0 015	0.013	0.013
Natural gas	0.0130	0.012	0.010	0.010
Fuel oil	0.0130	0.012	0.010	0.010

Technology data coal and hydrocarbons sector

For the base case, for both noncoking coal and coking coal, the characteristics of the average of different methods and grades of production are taken. There are appropriate bounds given on the availability. There is no import option for noncoking coal, though the option is available for coking coal. There is also a bound on the washery capacity for both noncoking and coking coal. It is assumed that 1.35 tonnes of coking coal is required for a tonne of soft coke to be manufactured. The demand for softcoke is from the domestic sector and the commercial sector. 50% of the coking coal goes towards meeting the needs of steel and softcoke, 25% is the middling production and 1 per cent is consumed in production. The requirement of noncoking coal is discussed in the section on Power. For natural gas, it is assumed that the domestic availability will be 100 Bcu.m. There is an import option allowed for natural gas, where the marginal imports are assumed to come from the Oman Offshore pipeline. For crude oil, again, there is a limit to the domestic availability, depending on the plans for exploration. Import options are allowed here for petroleum products, too, by limiting the capacity of refineries. It is assumed that 5 per cent of LPG production is through extraction from natural gas and 12% of natural gas goes into the petroleum industry. Of the total crude natural gas, 35% is the associated gas and the rest is free. The cost of production of all the fuels are the economic costs of supply which also includes transport cost for some average distance. Tables 7.2.7, 7.2.8, 7.2.9, 7.2.10 give some characteristics and bounds used for the different fuels for the study.

Table 7.2.7. Availability bound on primary fuels (million Gcal)

	1996/97	*1997–2001*	*2002–07*	*2007–11*
Noncoking coal	1080	1440	1687	2025
Coking coal	360	432	432	432
Crude	473	473	473	473
Natural gas	320	320	320	320

Table 7.2.8. Refining proportions for all petroleum products

	1996/97	*1997–2001*	*2002–07*	*2007–11*
LPG	0.025	0.025	0.025	0.025
Kerosene	0.112	0.112	0.112	0.112
Furnace oil	0.182	0.182	0.182	0.182
Diesel oil	0.368	0.368	0.368	0.368
Gasoline	0.076	0.076	0.076	0.076
Naphtha	0.094	0.094	0.094	0.094
Aviation turbine fuel	0.041	0.041	0.041	0.041

Table 7.2.9. Capacity of refining energy products (million Gcal)

	1996/97	*1997–2001*	*2002–07*	*2007–11*
Washed coking coal	120.0	150.0	180.0	180.0
Washed noncoking coal	112.5	225.0	337.5	450.0
Oil refineries	650.0	800.0	1000.0	1200.0

Notes

1/ Assuming Gross Calorific Value (GCV) of coking coal as 6 Gcal per tonne and 93 % of washery utilization

2/ Assuming 80% of distillate demand will be distillate production

Table 7.2.10. Cost of energy production by type (Rs. million per thousand Gcal)

	1996/97	*1997–2001*	*2002–07*	*2007–11*
Coking coal	0.0960	0.0960	0.0960	0.0960
Noncoking coal	0.0690	0.0690	0.0690	0.0690
Crude	0.1668	0.1668	0.1668	0.1668
Natural gas	0.1150	0.1150	0.1150	0.1150

Technology data power sector

The total demand for power is the sum of lighting load and demand for cooking, water heating and space heating from domestic and commercial sector, demand for electric drive and electric motor from the industrial sector, demand for irrigation and demand for rail transport. The technologies used in the power sector are conventional coal, gas, hydel and nuclear. For the scenarios, we have also considered clean coal technology-based technologies. There is no import option of power like interregional grids. The transmission and distribution losses are assumed to be reduced over the years from 22–17% in the base case. The system load factor is assumed to improve from 67.5–70% over the years even in the base case. The plant load factor for captive generation plants is assumed to improve from 66–70%. The following tables illustrate the data used for the model runs (Table 7.2.11, 7.2.12, 7.2.13, 7.2.14).

Table 7.2.11. Characteristics for power technologies

	1996/97	*1997–2001*	*2002–07*	*2007–11*
Secondary fuel-oil consumption (Gcal per GWh)	48.74	38 99	29.24	29.24
Natural gas required for combined cycle plant (Gcal per GWh)	2047.60	1911.00	1911.00	1911.00
Natural gas required for open cycle gas plant (Gcal per GWh)	2867.00	2774.00	2687 00	2606.00

Table 7.2.12. PLF for power technologies by vintage

	1996/97	*1997–2001*	*2002–07*	*2007–11*
Coal thermal	0.58	0.60	0.62	0 64
Gas CC	0 58	0.60	0.62	0 64
Gas OC	0.25	0.25	0 25	0.25
Run of river	0.35	0.35	0.35	0.35
Reservoir	0.35	0.35	0.35	0.35
Nuclear	0.58	0.60	0.62	0 64
Wind	0.20	0.20	0.20	0 20
Small hydel	0.30	0.30	0.30	0 30

Table 7.2.13. Auxiliary consumption for technologies

	1996/97	*1997–2001*	*2002–07*	*2007–11*
Coal thermal	0 09	0.080	0.07	0.070
Gas OC	0.03	0.030	0.03	0.030
Gas CC	0 01	0 010	0.01	0.010
Run of river	0 01	0.010	0.01	0.010
Reservoir	0.01	0.010	0 01	0.010
Nuclear	0.10	0 095	0 09	0.085

The technologies used for various periods of the load curve are :

Base load: Coal thermal, Gas (combined cycle), nuclear and hydel (run of the river).

Intermediate load. Coal thermal, Gas (combined cycle), nuclear and hydel (run of the river).

Low Peak: Gas (open cycle), hydel (run of the river), wind, small hydel and pump storage.

All characteristics related to power generation techniques are given in the following tables:

Table 7.2.14. Cost of technologies (Rs mill/GWh)

	1996/97	*1997-2001*	*2002-07*	*2007-11*
Coal thermal	1.140900	1.114900	1.090600	1.090600
Gas CC	1.036669	1.014400	0.993300	0.993300
Gas OC	1.615945	1 615945	1.615945	1 615945
Run of river	1 922183	1.922183	1.922183	1.922183
Reservoir	1.922183	1 922183	1.922183	1.922183
Nuclear	1.336100	1.303577	1 273100	1.273100
Wind	3.257000	3 257000	3 257000	3 257000
Micro hydel	1.829000	1.829000	1 829000	1 829000
Existing				
Coal thermal	0.1870	—	—	—
Gas CC	0 1575	—	—	—
Gas OC	0.2418	—	—	—
Run of river	0 2208	—	—	—
Reservoir	0.3312	—	—	—
Nuclear	0.109	1.226000	1 226000	1 226000
Wind	0.9153	—	—	—
Micro hydel	0.2874	—	—	—

Renewable energy forms

As part of the move towards environmentally benign technologies, greater emphasis is placed on renewables. Two of these have already been considered for the power sector, namely, wind and microhydel. Other biomass based forms are also considered as they are important from a developing country's point of view. In fact, the use of fuelwood is said to form the highest proportion of all energy forms used in the rural domestic sector. However, bounds are still placed on the use of these (Table 7.2.15).

Table 7.2.15. Availability bound on renewable energy (million Gcals)

	1996/97	*1997-2001*	*2002-07*	*2007-11*
Fuelwood	1282.00	1401 00	1496.00	1809.50
Dung-cake	373.00	4084 00	467.90	530.97
Crop waste	462.00	508 00	516.60	576.70
Biogas	6.25	8 86	5.10	5 10

APPENDIX 3

India energy environment database (IEEDB)

Introduction

Environmental degradation and its prevention have loomed large as a matter of public concern over the last few years. Policy-makers across the world have experimented with a vast variety of measures aimed at limiting pollution within safe levels. Irrespective of the measure, the success of any environmental intervention would depend on the availability of comprehensive information on the various polluting activities, the extent of pollutants generated, potential for mitigation, economics, health impacts etc..

Keeping this in view, Tata Energy Research Institute (TERI) has made a first-cut attempt at developing a computerized database which can maintain the data on emission standards. The database will require constant monitoring of the economic sectors and information needs to be collected, collated, and suitably repackaged for various categories of users. It could provide useful inputs for policy and planning in the area of environment emissions.

The objectives of IEEDB include the following:

- To allow users to have easy access to data:

  In IEEDB, most of the primary data is stored in a two-dimensional array similar to the format of most spreadsheets. This primary data is usually available in Indian journals published by government and private organizations. The package is very user-friendly and highly interactive. It is organized in such a way that one can quickly get the required data without much effort. The data is available on screen as well as in a printable file.
- To maintain data that are both accurate and consistent:

  The data of IEEDB is entered by specially trained personnel. In order to avoid any discrepancy, the entered data is checked and verified again from source. It can be updated easily.
- To ensure that data can be shared among users for a variety of applications :

  IEEDB helps the user to do some analysis on the primary data by allowing him or her to build algebraic equations. The derived results of the analysis can also be stored in the separate tables.

  The IEEDB software has a facility of computation through which one can do computation on the IEEDB primary data which can meet the specific requirement of the user.

- To allow users to construct their personal view of data without concern for the way the data are physically stored

The IEEDB package has six functional modules namely:

- select tables,
- select columns,
- compute columns,
- aggregation,
- query, and
- utility.

Database structure

The IEEDB data is structured in a heirarchical form with four different levels:

- sections,
- sectors,
- tables, and
- columns.

The IEEDB structure is displayed in Figure 1.

Level 1 : Sections

It comprises of four major sections *viz.* energy supply, energy demand, environment and economic indicators.

Level 2 : Sectors

Each section is divided into multiple sectors. The sectors are grouped as follows:

Energy supply : Renewables,
Biomass,
Power,
Oil and gas,
Coal.

Energy demand : Residential,
Commercial,
Industrial,
Transport,
Agriculture.

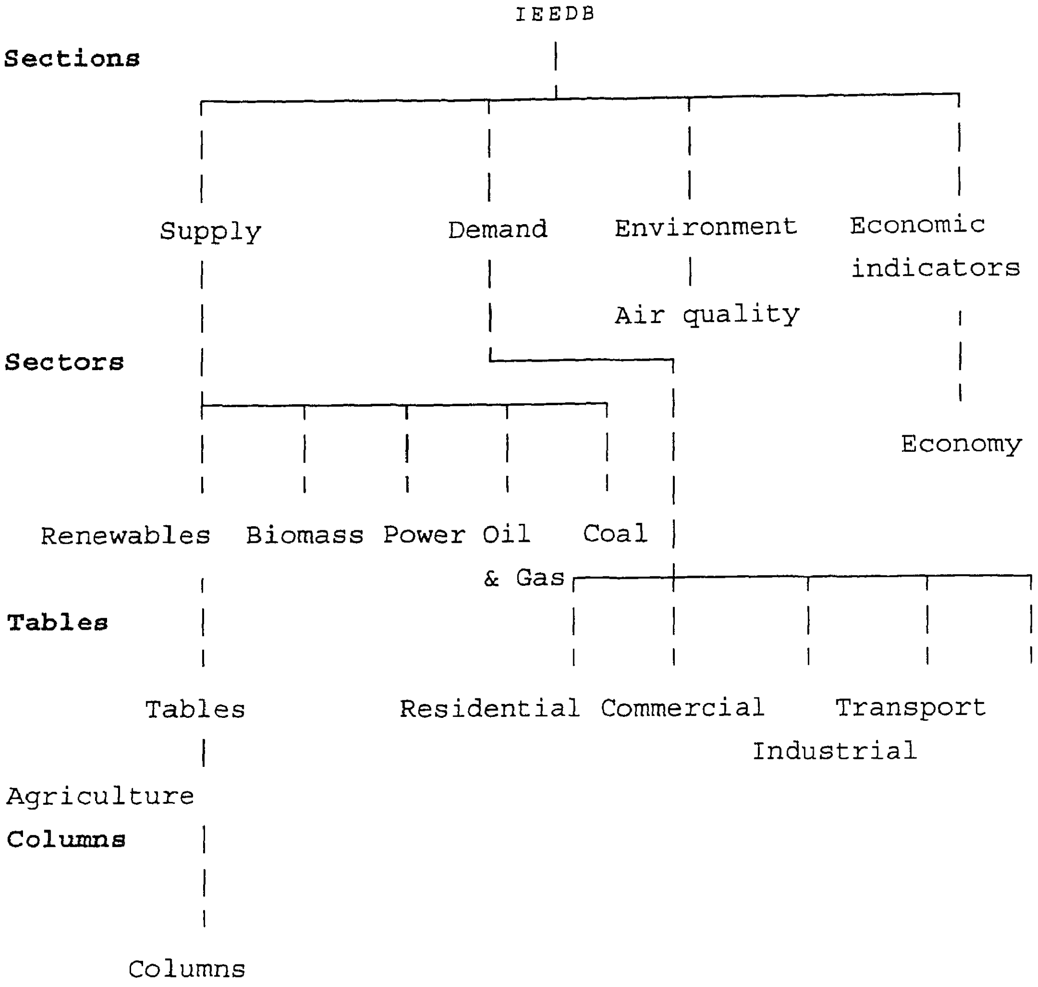

Figure 1. Energy database: overall structure

Environment : Air quality.

Economic indicators : Economy.

Level 3 : Tables

Each Sector is divided into Tables. Primarily, under each Sector, specific data are grouped under different Tables. Each Sector can have an unlimited number of Tables. Tables (of similar type) from same or multiple Sectors can be selected in groups.

Level 4 : Columns

Each Table consists of multiple columns depending upon the size of the data. These columns are of different types (numeric/character) depending on the type of data.

Table type

Data on each topic are organized separately in the form of Tables. Each Table is classified into a special class or type. This classification is based strictly on the type of data used which is explained below.

YR *Year-wise*

Generally tables contain chronological data spanning a period of time. Tables containing data records corresponding to each year are called *year-wise* data tables.

YRST · *Year and state-wise*

There are tables which contain data records that correspond to year and state and are called *year-wise and state-wise* data tables.

ST · *State-wise*

Tables which contain data records that correspond to state are called *state-wise* data tables.

MISC : *Miscellaneous*

Tables which contain reference data on any subject which are not time-specific or place-specific. Such tables are called *miscellaneous* data tables.

Grouping and computation can be done with columns from tables of the same type only. *MISC* type tables can be selected for viewing or computation only on single table basis i.e. *MISC* type tables cannot be selected in groups.

Features of IEEDB

Some of the prominent features of IEEDB are explained below:

User defined tables

These allow users to perform computations on selected columns. These computed columns are stored in a user-defined table which could be used as an independent table.

The user can generate new columns dynamically by computation, using user-defined expressions. These columns are called *computed columns*. The expressions are made of columns from the selected tables, standard algebraic functions and operators. A list of the allowable algebraic functions and operators is available online to the user for reference. Columns thus created are put under separate table(s) whose name(s) is/are given by users. User name is used at level two, to group the computed tables created by respective users. All user names are grouped under the fifth section called *computed table* (at level one).

Aggregation

This allows users to perform row-wise aggregation on selected columns. The aggregated results are stored in a user-defined table which could be used as an independent table.

Browsing the multiple tables

This allows users to simultaneously view selected or all columns from many tables from different sectors.

Work done on IEEDB

Collection, structuring and implementation of the data is complete, to the extent possible, for renewables, power, oil and gas, coal, residential, industrial, transport, agriculture and economy sectors. A sample printout of a file from each sectors is placed in Annexure I.

Identified topics.

The required topics are given below:

- Fuel-wise, sector-wise, enduse-wise demand for energy.
- Costs, including investment costs, production costs, and abatement costs of all existing technologies and future supply and demand sources.
- Cost of transporting fuels from supply source to demand source by the different modes.
- Fuel-wise import costs.
- Potential availability of each fuel.
- Emissions from the sources of supply and demand side.
- Efficiency parameters
    for conversion from primary to secondary energy.
    by device for different enduses.
- Availability of financial resources.
- Economic growth parameters.

Interface with Longrange Energy Alternative Planning system (LEAP) software

One of the essential requirements of the UNEP project is to update LEAP software with emission standards for pollutants (especially air) from all the identified sectors.

Primarily, IEEDB stores primary energy data which is usually published in Government/Private publications or collected through surveys/studies etc., in a two dimensional matrix form (like in most spreadsheets). The format of the data files of IEEDB database is similar to the format of the files of the LEAP software package. The data files can be shared. In fact, the output of the IEEDB database in terms of data files can be an input to the LEAP software package. The LEAP software package handles secondary data (or computed data) instead of the primary data.

Mechanism of transferring the LEAP data

Recently, TERI has procured the latest version of the LEAP software which will be updated with the data on emission standards of various pollutants. The updated data files of LEAP software will be copied in a separate floppy which will be sent to the concerned authorities for their use.